Long-Term Operation – Final Environmental Impact Statement

Appendix O – Fish and Aquatic Resources Technical Appendix

November 2024

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Contents

List of Tables xl
List of Figures lxvi

Appendix O Fish and Aquatic Resources Technical Appendix O-1
O.1 Affected Environment O-1
O.1.1 Fish and Aquatic Species Evaluated O-1
O.1.2 Trinity River O-4
O.1.2.1 Water Operations Management O-5
Flow O-5
Water Temperature O-5
O.1.2.2 Trinity and Klamath River Portions of the Study Area O-7
O.1.2.3 Trinity Reservoir O-8
Fish in Trinity Reservoir O-8
O.1.2.4 Lewiston Reservoir O-9
Fish in Lewiston Reservoir O-9
O.1.2.5 Trinity River from Lewiston Dam to the Confluence with Klamath River O-10
Fish in the Trinity River from Lewiston Dam to the Confluence with Klamath River O-10
Aquatic Habitat O-18
Fish Passage O-19
Hatcheries O-19
Predation O-19
O.1.2.6 Lower Klamath River From Confluence With Trinity River to Pacific Ocean O-20
Fish in the Lower Klamath River From the Trinity River Confluence to the Pacific Ocean O-20
Aquatic Habitat O-22
O.1.2.7 Harvest O-23
O.1.2.8 Disease O-24
O.1.3 Sacramento River O-25
O.1.3.1 Water Operations Management O-25
Flow O-25
Water Temperature O-25
O.1.3.2 Upper Sacramento River from Keswick Dam to the Delta O-26
Fish Evaluated in the Sacramento River O-26
O.1.3.3 Shasta Reservoir O-46
Fish in Shasta Reservoir O-46
O.1.3.4 Aquatic Habitat O-46
Holding Habitat O-46
Spawning Habitat O-47
Rearing Habitat O-50

O.1.3.5 Fish Passage and Entrainment O-51
O.1.3.6 Harvest O-52
O.1.3.7 Hatcheries O-55
O.1.3.8 Disease O-56
O.1.3.9 Predation O-57
O.1.4 Battle Creek O-58
O.1.4.1 Coleman National Fish Hatchery O-58
O.1.4.2 Restoration O-58
O.1.5 Clear Creek O-59
O.1.5.1 Water Operations Management O-60
Flow O-60
Water Temperature O-60
O.1.5.2 Clear Creek below Whiskeytown Reservoir O-61
Fish Evaluated in Clear Creek O-61
O.1.5.3 Whiskeytown Reservoir O-65
Fish in Whiskeytown Reservoir and Upper Clear Creek O-66
O.1.5.4 Aquatic Habitat O-66
Spawning Habitat O-66
Rearing Habitat O-67
O.1.5.5 Fish Passage O-67
O.1.6 Lower American River O-67
O.1.6.1 Water Operations Management O-68
Flow O-68
Water Temperature O-69
O.1.6.2 Lower American River between Lake Natoma and the Sacramento River O-69
Fish Evaluated in the Lower American River O-69
O.1.6.3 Folsom Reservoir and Lake Natoma O-75
Fish in Folsom Reservoir and Lake Natoma O-75
O.1.6.4 Aquatic Habitat O-75
O.1.6.5 Fish Passage O-76
O.1.6.6 Hatcheries O-77
O.1.6.7 Disease O-78
O.1.6.8 Predation O-79
O.1.6.9 Harvest O-79
O.1.7 Stanislaus River O-82
O.1.7.1 Water Operations Management O-82
Flow O-82
Water Temperature O-90
Dissolved Oxygen O-91
O.1.7.2 Lower Stanislaus River between New Melones Reservoir and San Joaquin River O-91
Fish Evaluated in the Stanislaus River O-91
Fall-run Chinook Salmon, Central Valley ESU O-92
Steelhead, California Central Valley DPS O-93
Pacific Lamprey O-94

Western River Lamprey O-95
Hardhead O-95
American Shad O-95
Threadfin Shad O-95
Striped Bass O-96
Black Basses O-96
O.1.7.3 New Melones Reservoir, Tulloch Reservoir, and Goodwin Dam O-98
Fish in New Melones Reservoir, Tulloch Reservoir, and Above Goodwin Dam O-99
O.1.7.4 Aquatic Habitat O-99
Spawning and Rearing Habitat O-100
Floodplain Habitat O-100
O.1.7.5 Fish Passage and Entrainment O-101
O.1.7.6 Predation O-101
O.1.8 San Joaquin River O-102
O.1.8.1 Water Operations Management O-103
Flow O-103
Water Temperature O-103
O.1.8.2 Fish Evaluated in the San Joaquin River O-104
Fall-run Chinook Salmon O-104
Steelhead, California Central Valley DPS O-105
Green Sturgeon, Southern DPS O-105
White Sturgeon O-105
Pacific Lamprey O-106
Western River Lamprey O-106
Sacramento Splittail O-107
Hardhead O-107
Sacramento Hitch O-107
American Shad O-107
Threadfin Shad O-107
Striped Bass O-108
Black Basses O-108
O.1.8.3 Aquatic Habitat O-108
O.1.8.4 Fish Passage O-108
O.1.8.5 Hatcheries O-108
O.1.8.6 Predation O-109
O.1.9 Bay-Delta O-109
O.1.9.1 Fish and Aquatic Species Evaluated in the Bay-Delta O-109
Winter-run Chinook Salmon, Sacramento River ESU O-111
Spring-run Chinook Salmon, Central Valley ESU O-112
Fall-/Late Fall-run Chinook Salmon, Central Valley ESU O-113
Steelhead, California Central Valley DPS O-114
Green Sturgeon, Southern DPS O-116
White Sturgeon O-117
Delta Smelt O-119
Longfin Smelt, Bay-Delta DPS O-124

Pacific Lamprey O-127
Western River Lamprey O-128
Sacramento Splittail O-128
Hardhead O-128
Sacramento Hitch O-129
American Shad O-129
Threadfin Shad O-130
Striped Bass O-130
Black Basses O-131
Starry Flounder O-131
Coastal Pelagic Species O-132
O.1.9.2 Aquatic Habitat O-134
Delta O-134
Yolo Bypass O-136
Suisun Bay and Marsh O-137
O.1.9.3 Nutrients and Food Web Support O-138
O.1.9.4 Turbidity O-139
O.1.9.5 Contaminants O-140
Fish Passage and Entrainment O-141
North Delta Fish Passage and Entrainment O-141
Yolo Bypass O-142
Central and South Delta Fish Passage and Entrainment O-143
Suisun Bay and Marsh O-147
O.1.9.6 Disease O-148
O.1.9.7 Nonnative Invasive Species O-148
O.1.9.8 Predation O-150
O.1.9.9 Aquatic Macrophytes O-151
O.1.10 San Francisco Bay Area O-151
O.1.10.1 Contra Loma Reservoir O-152
O.1.10.2 San Justo Reservoir O-152
O.1.10.3 South Bay Aqueduct Reservoirs O-152
O.1.10.4 Los Vaqueros Reservoir O-152
O.1.10.5 East Bay Municipal Utility District Reservoirs O-152
O.1.11 CVP and SWP Service Areas (south to Diamond Valley) O-153
O.1.11.1 San Luis Reservoir O-153
O.1.11.2 Delta Mendota Canal and California Aqueduct Intertie O-153
O.1.11.3 Southern California O-154
State Water Project Reservoirs O-154
O.1.12 Nearshore Pacific Ocean Habitat of Southern Resident Killer Whale O-155
O.1.12.1 Pacific Ocean Habitat of the Killer Whale O-155
O.2 Methods and Tools O-158
O.2.1 CalSim 3 ..... O-158
O.2.2 HEC-5Q O-159
O.2.3 Reclamation Temperature Model O-159
O.2.4 DSM2 ..... O-159
O.2.5 Interactive Object-Oriented Simulation O-159

O.2.6 Oncorhynchus Bayesian Analysis O-160
O.2.7 Central Valley Project Implementation Act Science Integration Team Lifecycle Models O-160
O.2.8 Delta Smelt Life Cycle Model O-160
O.2.9 Survival, Travel time, and Routing Simulation O-160
O.2.10 Delta Passage Model O-161
O.2.11 Particle Tracking Model O-162
O.2.12 Ecological Particle Tracking Model O-162
O.2.13 Zone of Influence O-162
O.2.14 Negative Binomial Model O-162
O.2.15 Salvage Density Model O-163
O.2.16 Winter-Run Chinook Salmon Coded-Wire Tag Loss O-163
O.2.17 Longfin Smelt Salvage | OMR O-163
O.2.18 Flow into Junctions O-164
O.2.19 Zooplankton Delta Outflow O-164
O.2.20 XT O-164
O.2.21 Flow Threshold Salmon Survival O-165
O.2.22 Delta Outflow | Sturgeon Year Class Index O-165
O.2.23 Delta Outflow | Bay-Delta Species Abundance O-165
O.2.24 Longfin Smelt Spring Outflow O-165
O.2.25 Revised Maunder and Deriso O-166
O.2.26 Winter-Run Chinook Salmon Juvenile Production Index O-166
O.2.27 Sacramento River Weighted Usable Area O-167
O.2.28 Sacramento River Dewatering Analysis O-167
O.2.29 Sacramento River Juvenile Stranding Analysis O-167
O.2.30 Salmort Egg Mortality models O-168
O.2.31 Winter-run Temperature Dependent Mortality O-168
O.2.32 Sacramento River Temperature Analysis O-169
O.2.33 Clear Creek Temperature Analysis O-169
O.2.34 Clear Creek Weighted Usable Area (spawning and rearing) O-169
O.2.35 American River Weighted Usable Area O-169
O.2.36 American River Temperature Analysis O-169
O.2.37 American River Redd Dewatering Analysis O-169
O.2.38 Stanislaus River Weighted Usable Area O-169
O.2.39 Stanislaus River Temperature Analysis O-169
O.2.40 Central Valley Project Improvement Act Science Integration Team Decision Support Model Habitat Models O-170
O.3 No Action Alternative O-171
O.3.1 Sacramento River Winter-Run Chinook Salmon ESU O-171
O.3.1.1 Sacramento River O-171
No Action Alternative Components and Winter-run Chinook Salmon O-171
O.3.1.2 Bay-Delta O-173
No Action Alternative Components and Winter-run Chinook Salmon O-173
O.3.2 Central Valley Spring-Run Chinook Salmon ESU O-175
O.3.2.1 Sacramento River O-175
No Action Alternative Components and Spring-run Chinook Salmon O-175

O.3.2.2 Clear Creek O-176
No Action Alternative Components and Spring-run Chinook Salmon O-176
O.3.2.3 Bay-Delta O-177
No Action Alternative Components and Spring-run Chinook Salmon O-177
O.3.3 California Central Valley Steelhead DPS O-179
O.3.3.1 Sacramento River O-179
No Action Alternative Components and Steelhead O-179
O.3.3.2 Clear Creek O-180
No Action Alternative Components and Steelhead O-180
O.3.3.3 Lower American River O-181
No Action Alternative Components and Steelhead O-181
O.3.3.4 Bay-Delta O-182
No Action Alternative Components and Steelhead O-182
O.3.3.5 San Joaquin River O-184
No Action Alternative and Steelhead O-184
O.3.3.6 Stanislaus River O-184
No Action Alternative Components and Steelhead O-184
O.3.4 Southern DPS Green Sturgeon O-185
O.3.4.1 Sacramento River O-186
No Action Alternative Components and Green Sturgeon O-186
O.3.4.2 San Joaquin River O-186
O.3.4.3 Bay-Delta O-187
No Action Alternative Components and Green Sturgeon O-187
O.3.5 Delta Smelt O-188
O.3.5.1 Bay-Delta O-188
No Action Alternative Components and Delta Smelt O-188
O.3.6 Longfin Smelt O-190
O.3.6.1 Bay Delta O-190
No Action Alternative Components and Longfin Smelt O-190
O.3.7 Fall-run and Late Fall-run Chinook Salmon ESU O-191
O.3.7.1 Sacramento River O-191
No Action Alternative Components and Fall-run and Late Fall-run Chinook Salmon O-191
O.3.7.2 Clear Creek O-192
No Action Alternative Components and Fall-run and Late Fall-run Chinook Salmon O-192
O.3.7.3 Lower American River O-193
No Action Alternative Components and Fall-run Chinook Salmon O-193
O.3.7.4 Stanislaus River O-193
No Action Alternative Components and Fall-run Chinook Salmon O-193
O.3.7.5 San Joaquin River O-194
No Action Alternative and Fall-run Chinook Salmon O-194
O.3.7.6 Bay-Delta O-194
No Action Alternative Components and Fall-run and Late Fall-run Chinook Salmon O-194
O.3.8 White Sturgeon O-195

O.3.8.1 Sacramento River O-195
No Action Alternative Components and White Sturgeon O-195
O.3.8.2 Lower American River O-196
No Action Alternative Components and White sturgeon O-196
O.3.8.3 San Joaquin River O-197
No Action Alternative and White Sturgeon O-197
O.3.8.4 Bay-Delta O-197
No Action Alternative Components and White Sturgeon O-197
O.3.9 Native Minnows O-198
O.3.9.1 Sacramento River O-198
No Action Alternative Components and Native Minnows O-198
O.3.9.2 Clear Creek O-199
No Action Alternative Components and Hardhead O-199
O.3.9.3 Lower American River O-199
No Action Alternative Components and Native Minnows O-199
O.3.9.4 Stanislaus River O-200
No Action Alternative Components and Hardhead O-200
O.3.9.5 San Joaquin River O-201
No Action Alternative and Native Minnows O-201
O.3.9.6 Bay-Delta O-201
No Action Alternative Components and Native Minnows O-201
O.3.10 Pacific Lamprey O-202
O.3.10.1 Trinity River O-202
Spawning and Egg Incubation O-202
Ammocoete Rearing and Emigration O-203
Adult Upstream Migration and Holding O-203
O.3.10.2 Sacramento River O-204
No Action Alternative Components and Pacific Lamprey O-204
O.3.10.3 Clear Creek O-205
No Action Alternative Components and Pacific Lamprey O-205
O.3.10.4 Lower American River O-205
No Action Alternative Components and Pacific Lamprey O-205
O.3.10.5 Stanislaus River O-206
No Action Alternative Components and Pacific Lamprey O-206
O.3.10.6 San Joaquin River O-206
No Action Alternative and Pacific Lamprey O-206
O.3.10.7 Bay-Delta O-206
No Action Alternative Components and Pacific Lamprey O-206
O.3.11 Western River Lamprey O-208
O.3.11.1 Sacramento River O-208
No Action Alternative Components and Western River Lamprey O-208
O.3.11.2 Lower American River O-208
No Action Alternative Components and Western River Lamprey O-208
O.3.11.3 Stanislaus River O-209
No Action Alternative Components and Western River Lamprey O-209
O.3.11.4 San Joaquin River O-210

No Action Alternative and Western River Lamprey O-210
O.3.11.5 Bay-Delta..... O-210
No Action Alternative Components and Western River Lamprey O-210
O.3.12 Striped Bass O-211
O.3.12.1 Sacramento River O-211
No Action Alternative Components and Striped Bass O-211
O.3.12.2 Lower American River O-212
No Action Alternative Components and Striped Bass O-212
O.3.12.3 Stanislaus River..... O-212
No Action Alternative Components and Striped Bass O-212
O.3.12.4 Bay-Delta..... O-213
No Action Alternative Components and Striped Bass O-213
O.3.13 American Shad..... O-214
O.3.13.1 Sacramento River O-214
No Action Alternative Components and American Shad..... O-214
O.3.13.2 Lower American River O-215
No Action Alternative Components and American Shad..... O-215
O.3.13.3 Stanislaus River..... O-216
No Action Alternative Components and American Shad..... O-216
O.3.13.4 Bay-Delta..... O-216
No Action Alternative Components and American Shad..... O-216
O.3.14 Threadfin Shad..... O-218
O.3.14.1 Sacramento River O-218
No Action Alternative Components and Threadfin Shad..... O-218
O.3.14.2 Lower American River O-219
No Action Alternative Components and Threadfin Shad..... O-219
O.3.14.3 Stanislaus River..... O-219
No Action Alternative Components and Threadfin Shad..... O-219
O.3.14.4 Bay-Delta..... O-220
No Action Alternative Components and Threadfin Shad..... O-220
O.3.15 Black Basses O-221
O.3.15.1 Sacramento River O-221
No Action Alternative Components and Black Basses O-221
O.3.15.2 Lower American River O-222
No Action Alternative Components and Black Basses O-222
O.3.15.3 Stanislaus River..... O-222
No Action Alternative Components and Black Basses O-222
O.3.15.4 Bay-Delta..... O-223
No Action Alternative Components and Black Basses O-223
O.3.16 Starry Flounder O-224
O.3.16.1 Bay-Delta..... O-224
No Action Alternative Components and Starry Flounder O-224
O.3.17 Coastal Pelagic Species..... O-226
O.3.17.1 Bay-Delta..... O-226
No Action Alternative Components and Coastal Pelagic Species O-226
O.3.18 Southern Oregon/Northern California Coast Coho Salmon ESU..... O-228

O.3.18.1 Trinity River O-228
Potential Changes to Coho Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations O-228
Potential Changes to Coho Salmon Juvenile Rearing and Emigration from Seasonal Operations O-229
Potential Changes to Coho Salmon Adult Upstream Migration and Holding from Seasonal Operations O-230
O.3.19 Upper Klamath-Trinity River Spring-Run Chinook Salmon ESU O-231
O.3.19.1 Trinity River O-231
Potential Changes to Spring-run Chinook Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations O-231
Potential Changes to Spring-run Chinook Salmon Juvenile Rearing and Emigration from Seasonal Operations O-232
Potential Changes to Spring-run Chinook Salmon Adult Upstream Migration and Holding from Seasonal Operations O-233
O.3.20 Upper Klamath-Trinity River Fall-Run Chinook Salmon ESU O-233
O.3.20.1 Trinity River O-233
Potential Changes to Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations O-234
Potential Changes to Fall-run Chinook Salmon Juvenile Rearing and Emigration from Seasonal Operations O-235
Potential Changes to Fall-run Chinook Salmon Adult Upstream Migration and Holding from Seasonal Operations O-236
O.3.21 Klamath Mountains Province Steelhead DPS O-236
O.3.21.1 Trinity River O-236
Potential Changes to Steelhead Spawning and Egg/Alevin Incubation from Seasonal Operations O-237
Potential Changes to Steelhead Juvenile Rearing and Emigration from Seasonal Operations O-238
Potential Changes to Steelhead Adult Migration and Holding from Seasonal Operations O-238
O.3.22 Northern DPS Green Sturgeon O-239
O.3.22.1 Trinity River O-239
Potential Changes to Northern DPS Green Sturgeon Spawning and Egg Incubation from Seasonal Operations O-239
Larval and Juvenile Rearing and Emigration O-239
Adult Upstream Migration and Holding O-240
O.3.23 Eulachon O-240
O.3.23.1 Potential Changes to Eulachon Spawning and Egg Incubation from Seasonal Operations O-240
O.3.23.2 Potential Changes to Eulachon Larval Emigration from Seasonal Operations O-241
O.3.23.3 Potential Changes to Eulachon Adult Upstream Migration from Seasonal Operations O-241
O.3.24 Coastal Cutthroat Trout O-241

O.3.24.1 Lower Klamath River from Confluence with Trinity River to Pacific Ocean O-241
Potential Changes to Coastal Cutthroat Trout Spawning and Egg Incubation from Seasonal Operations O-241
Potential Changes to Coastal Cutthroat Trout Juvenile Rearing and Emigration from Seasonal Operations O-241
Potential Changes to Coastal Cutthroat Trout Adult Holding and Migration from Seasonal Operations O-242
O.3.25 Brown Trout O-242
O.3.25.1 Trinity River O-242
Potential Changes to Brown Trout Spawning and Egg Incubation from Seasonal Operations O-243
Potential Changes to Brown Trout Juvenile Rearing and Emigration from Seasonal Operations O-243
Potential Changes to Brown Trout Adult Holding and Migration from Seasonal Operations O-243
O.3.26 Trinity Reservoir Species O-244
O.3.26.1 Trinity Reservoir O-244
Potential Changes to Trinity Reservoir Fish Species Spawning and Egg Incubation from Seasonal Operations O-244
Potential Changes to Trinity Reservoir Fish Species Larval and Juvenile Rearing and Emigration from Seasonal Operations O-244
Potential changes to Trinity Reservoir fish species adult holding from seasonal operations O-245
O.3.27 Central Valley Reservoir Species O-245
O.3.27.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations O-245
O.3.28 Delta-Mendota Canal/California Aqueduct Species O-245
O.3.28.1 Potential Changes to Delta-Mendota Canal and California Aqueduct Species from Seasonal Operations O-245
O.3.29 San Luis Reservoir Species O-246
O.3.29.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations O-246
O.3.30 Southern Resident Killer Whale O-246
O.3.30.1 Nearshore Pacific Ocean on the California Coast O-246
O.4 Alternative 1 ..... O-247
O.4.1 Trinity River O-247
O.4.1.1 Trinity River flows below Lewiston Dam O-247
O.4.1.2 Trinity Reservoir Storage O-247
O.4.1.3 Trinity River Water Temperatures below Lewiston Dam O-250
O.4.2 Sacramento River O-253
O.4.2.1 Sacramento River Flows below Keswick Dam O-254
O.4.2.2 Sacramento River Flows below Red Bluff Diversion Dam O-254
O.4.2.3 Sacramento River Flows at Wilkins Slough O-254
O.4.2.4 Sacramento River Flows at Hamilton City O-254
O.4.3 Bay-Delta O-259

O.4.3.1 Delta X2 ..... O-259
O.4.3.2 Delta Exports O-260
O.4.3.3 Delta Outflow O-260
O.4.3.4 Delta OMR O-260
O.4.3.5 Sacramento River at Rio Vista O-260
O.4.4 Clear Creek O-266
O.4.4.1 Clear Creek below Whiskeytown Dam O-266
O.4.5 American River O-268
O.4.5.1 American River for Folsom Reservoir Storage O-269
O.4.5.2 American River below Nimbus Dam O-269
O.4.5.3 American River at H Street O-269
O.4.6 Stanislaus River O-273
O.4.6.1 Stanislaus River below Goodwin Dam O-273
O.4.6.2 Stanislaus River at Mouth O-273
O.4.7 San Joaquin River O-276
O.4.7.1 San Joaquin River at Vernalis O-276
O.4.8 Sacramento River Winter-run Chinook Salmon ESU O-278
O.4.8.1 Sacramento River O-278
Spawning and Egg/Alevin Incubation O-278
Juvenile Rearing and Emigration O-284
Adult Upstream Migration and Holding O-290
O.4.8.2 Bay-Delta O-292
Juvenile Rearing and Emigration O-292
O.4.9 Central Valley Spring-run Chinook Salmon ESU O-304
O.4.9.1 Sacramento River O-304
Spawning and Egg/Alevin Incubation O-304
Juvenile–Yearling Rearing and Emigration O-308
Adult Upstream Migration and Holding O-313
O.4.9.2 Clear Creek O-315
Spawning and Egg Incubation O-315
Juvenile–Yearling Rearing and Emigration O-317
Adult Upstream Migration and Holding O-320
O.4.9.3 Bay-Delta O-321
Juvenile–Yearling Rearing and Emigration O-321
O.4.10 California Central Valley Steelhead DPS O-325
O.4.10.1 Sacramento River O-325
Spawning and Egg Incubation O-325
Juvenile Rearing and Emigration O-328
Adult Upstream Migration and Holding O-332
Kelt Emigration O-335
O.4.10.2 Clear Creek O-338
Spawning and Egg Incubation O-338
Juvenile Rearing and Emigration O-340
Adult Upstream Migration and Holding O-343
Kelt Emigration O-346
O.4.10.3 Lower American River O-348

Spawning and Egg Incubation O-348
Juvenile Rearing and Emigration O-351
Adult Upstream Migration and Holding O-354
Kelt Emigration O-356
O.4.10.4 Bay-Delta O-359
Juvenile Rearing and Emigration O-359
O.4.10.5 San Joaquin River O-362
Juvenile Emigration O-362
Adult Upstream Migration and Holding O-363
O.4.10.6 Stanislaus River O-364
Spawning and Egg Incubation O-364
Juvenile Rearing and Emigration O-367
Adult Upstream Migration and Holding O-370
Kelt Emigration O-373
O.4.11 Southern DPS Green Sturgeon O-375
O.4.11.1 Sacramento River O-375
Spawning and Egg Incubation O-375
Larval and Juvenile Rearing and Emigration O-378
Adult Upstream Migration and Holding O-380
O.4.11.2 San Joaquin River O-383
Potential Changes to Green Sturgeon from Seasonal Operations O-383
O.4.11.3 Bay-Delta O-383
Larval and Juvenile Rearing and Emigration O-383
Adult Upstream Migration and Holding O-388
O.4.12 Delta Smelt O-388
O.4.12.1 Bay-Delta O-388
Adult Migration and Spawning O-388
Eggs and Larvae O-392
Juveniles O-395
O.4.13 Longfin Smelt O-398
O.4.13.1 Bay Delta O-398
Adult Migration and Spawning O-398
Eggs and Larvae O-402
Juveniles O-405
O.4.14 Fall-run and Late Fall-run Chinook Salmon ESU O-407
O.4.14.1 Sacramento River O-407
Spawning and Egg/Alevin Incubation O-407
Juvenile Rearing and Emigration O-413
Adult Upstream Migration and Holding O-421
O.4.14.2 Clear Creek O-426
Spawning and Egg Incubation O-426
Juvenile Rearing and Emigration O-429
Adult Upstream Migration and Holding O-434
O.4.14.3 Lower American River O-437
Spawning and Egg Incubation O-437
Juvenile Rearing and Emigration O-440

Adult Upstream Migration and Holding O-443
O.4.14.4 San Joaquin River O-446
Potential Changes to Fall-run Chinook Salmon from Seasonal Operations ... O-446
O.4.14.5 Bay-Delta O-446
Juvenile Rearing and Emigration O-446
O.4.14.6 Stanislaus River O-451
Spawning and Egg Incubation O-451
Juvenile Rearing and Emigration O-453
Adult Upstream Migration and Holding O-456
O.4.15 White Sturgeon O-458
O.4.15.1 Sacramento River O-458
Spawning and Egg Incubation O-458
Larval and Juvenile Rearing and Emigration O-460
Adult Upstream Migration and Holding O-462
O.4.15.2 Lower American River O-463
Potential Changes to White Sturgeon from Seasonal Operations O-463
O.4.15.3 San Joaquin River O-465
Potential Changes to White Sturgeon from Seasonal Operations O-465
O.4.15.4 Bay-Delta O-466
Juvenile Rearing and Emigration O-466
Subadult and Adult Residency O-468
O.4.16 Native Minnows O-469
O.4.16.1 Sacramento River O-469
Sacramento Splittail, Hardhead, and Sacramento Hitch O-469
O.4.16.2 Clear Creek O-473
Hardhead O-473
O.4.16.3 Lower American River O-474
Hardhead and Sacramento Splittail O-474
O.4.16.4 Stanislaus River O-478
Hardhead O-478
O.4.16.5 San Joaquin River O-480
Sacramento Splittail, Hardhead, and Sacramento Hitch O-480
O.4.16.6 Bay-Delta O-481
Hardhead, Sacramento Hitch, and Sacramento Splittail O-481
O.4.17 Pacific Lamprey O-487
O.4.17.1 Trinity River O-487
Spawning and Egg Incubation O-487
Adult Upstream Migration and Holding O-489
O.4.17.2 Sacramento River O-490
Spawning and Egg Incubation O-490
Ammocoete Rearing and Emigration O-491
O.4.17.3 Clear Creek O-493
Spawning and Egg Incubation O-493
Ammocoete Rearing and Emigration O-494
O.4.17.4 Lower American River O-496
Spawning and Egg Incubation O-496

Ammocoete Rearing and Emigration O-497
O.4.17.5 Stanislaus River O-499
Spawning and Egg Incubation O-499
Ammocoete Rearing and Emigration O-501
O.4.17.6 San Joaquin River O-503
Ammocoete Rearing and Emigration O-503
O.4.17.7 Bay-Delta O-503
Potential Changes to Pacific Lamprey from Seasonal Operations O-504
Potential Changes to Entrainment of Pacific Lamprey O-504
O.4.18 Western River Lamprey O-506
O.4.18.1 Sacramento River O-506
Spawning and Egg Incubation O-506
Ammocoete Rearing and Emigration O-508
O.4.18.2 Lower American River O-509
Spawning and Egg Incubation O-509
Ammocoete Rearing and Emigration O-511
O.4.18.3 Stanislaus River O-513
Spawning and Egg Incubation O-513
Ammocoete Rearing and Emigration O-515
O.4.18.4 San Joaquin River O-517
Ammocoete Rearing and Emigration O-517
O.4.18.5 Bay-Delta O-518
Potential Changes to Western River Lamprey from Seasonal Operations O-518
Potential Changes to Entrainment of Western River Lamprey O-518
O.4.19 Striped Bass O-520
O.4.19.1 Sacramento River O-520
Spawning and Egg Incubation O-520
Laval–Juvenile Rearing and Emigration O-522
O.4.19.2 Lower American River O-523
Adults O-523
Juvenile Rearing O-525
O.4.19.3 Stanislaus River O-526
Spawning and Egg Incubation O-526
Laval–Juvenile Rearing and Emigration O-528
O.4.19.4 San Joaquin River O-530
Potential Changes to Striped Bass from Seasonal Operations O-530
O.4.19.5 Bay-Delta O-530
Potential Changes to Striped Bass from Seasonal Operations O-531
Potential Changes to Entrainment of Striped Bass O-531
O.4.20 American Shad O-533
O.4.20.1 Sacramento River O-533
Spawning and Larval Rearing O-533
Juvenile Rearing and Emigration O-534
O.4.20.2 Lower American River O-536
Spawning and Larval Rearing O-536
Juvenile Rearing and Emigration O-538

O.4.20.3 Stanislaus River O-540
Spawning and Larval Rearing O-540
Juvenile Rearing and Emigration O-541
O.4.20.4 San Joaquin River O-543
Spawning and Larval Rearing O-543
Juvenile Rearing and Emigration O-544
O.4.20.5 Bay-Delta O-544
Potential Changes to American Shad from Seasonal Operations O-545
Potential Changes to Entrainment of American Shad O-545
O.4.21 Threadfin Shad O-547
O.4.21.1 Sacramento River O-547
Potential Changes to Threadfin Shad from Seasonal Operations O-547
O.4.21.2 Lower American River O-548
Potential Changes to Threadfin Shad from Seasonal Operations O-548
O.4.21.3 Stanislaus River O-550
Potential Changes to Threadfin Shad from Seasonal Operations O-550
O.4.21.4 San Joaquin River O-551
Potential Changes to Threadfin Shad from Seasonal Operations O-552
O.4.21.5 Bay-Delta O-552
Potential Changes to Threadfin Shad from Seasonal Operations O-552
Potential Changes to Entrainment of Threadfin Shad O-552
O.4.22 Black Basses O-554
O.4.22.1 Three Micropterus spp. O-554
Largemouth Bass O-554
Smallmouth Bass O-554
Spotted Bass O-554
O.4.22.2 Sacramento River O-554
Spawning O-554
Non-Spawning Adult O-556
O.4.22.3 Lower American River O-559
Spawning O-559
Non-Spawning Adult O-561
O.4.22.4 Stanislaus River O-564
Spawning O-564
Non-Spawning Adult O-566
O.4.22.5 San Joaquin River O-568
Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations O-568
O.4.22.6 Bay-Delta O-569
Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations O-569
Potential Changes to Entrainment of Largemouth Bass O-569
Potential Changes to Entrainment of Smallmouth Bass O-571
Potential Changes to Entrainment of Spotted Bass O-572
O.4.23 Starry Flounder O-574
O.4.23.1 Bay-Delta O-574

Potential Changes to Starry Flounder from Seasonal Operations O-574
Potential Changes to Entrainment of Starry Flounder O-575
O.4.24 Coastal Pelagic Species O-577
O.4.24.1 Potential Changes to Northern Anchovy and Pacific Herring from Seasonal Operations O-577
O.4.24.2 Potential Changes to Entrainment of Northern Anchovy and Pacific Herring O-577
O.4.25 Southern Oregon/Northern California Coast Coho Salmon ESU O-577
O.4.25.1 Trinity River O-577
Spawning and Egg/Alevin Incubation O-577
Juvenile Rearing and Emigration O-580
Adult Upstream Migration and Holding O-582
O.4.26 Upper Klamath-Trinity River Spring-run Chinook Salmon ESU O-583
O.4.26.1 Trinity River O-583
Spawning and Egg/Alevin Incubation O-583
Juvenile Rearing and Emigration O-584
Adult Upstream Migration and Holding O-586
O.4.27 Upper Klamath-Trinity River Fall-run Chinook Salmon ESU O-586
O.4.27.1 Trinity River O-586
Spawning and Egg/Alevin Incubation O-586
Juvenile Rearing and Emigration O-588
Adult Upstream Migration and Holding O-589
O.4.28 Klamath Mountains Province Steelhead DPS O-590
O.4.28.1 Trinity River O-590
Spawning and Egg/Alevin Incubation O-590
Juvenile Rearing and Emigration O-591
Adult Upstream Migration and Holding O-593
O.4.29 Northern DPS Green Sturgeon O-595
O.4.29.1 Trinity River O-595
Spawning and Egg Incubation O-595
Larval and Juvenile Rearing and Emigration O-595
Adult Upstream Migration and Holding O-596
O.4.30 Eulachon O-597
O.4.30.1 Lower Klamath River from Confluence with Trinity River to Pacific Ocean O-597
Spawning and Egg Incubation O-597
Adult Upstream Migration O-599
O.4.31 Coastal Cutthroat Trout O-600
O.4.31.1 Lower Klamath River from Confluence with Trinity River to Pacific Ocean O-600
Spawning and Egg Incubation O-600
Juvenile Rearing and Emigration O-600
Adult Holding and Migration O-601
O.4.32 Brown Trout O-602
O.4.32.1 Trinity River O-602
Spawning and Egg Incubation O-602

Juvenile Rearing and Emigration O-603
Adult Holding and Migration O-604
O.4.33 Trinity Reservoir Species O-605
O.4.33.1 Trinity Reservoir O-605
Spawning and Egg Incubation O-605
Larval and Juvenile Rearing and Emigration O-606
O.4.34 Central Valley Reservoir Species O-607
O.4.34.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations O-607
Methods O-607
Results O-608
O.4.35 Delta-Mendota Canal/California Aqueduct Species O-619
O.4.35.1 Potential Changes to Delta-Mendota Canal/California Aqueduct Species from Seasonal Operations O-619
O.4.36 San Luis Reservoir Species O-619
O.4.36.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations O-619
Warmwater Species O-619
O.4.37 Southern Resident Killer Whale O-620
O.4.37.1 Nearshore Pacific Ocean on the California Coast O-620
O.5 Alternative 2 ..... O-621
O.5.1 Trinity River O-621
O.5.1.1 Trinity River Flows below Lewiston Dam O-621
O.5.1.2 Trinity Reservoir Storage O-622
O.5.2 Sacramento River O-632
O.5.2.1 Sacramento River Flows below Keswick Dam O-633
O.5.2.2 Sacramento River Flows below Red Bluff Diversion Dam O-633
O.5.2.3 Sacramento River Flows at Wilkins Slough O-633
O.5.2.4 Sacramento River Flows at Hamilton City O-633
O.5.3 Bay-Delta O-650
O.5.3.1 Delta X2 ..... O-650
O.5.3.2 Delta Exports O-650
O.5.3.3 Delta Outflow O-650
O.5.3.4 Delta OMR O-651
O.5.3.5 Sacramento River flow at Rio Vista O-651
O.5.4 Clear Creek O-672
O.5.4.1 Clear Creek below Whiskeytown Dam O-672
O.5.5 Lower American River O-677
O.5.5.1 Folsom Reservoir Storage O-677
O.5.5.2 Lower American River below Nimbus Dam O-677
O.5.5.3 Lower American River at H Street O-677
O.5.6 Stanislaus River O-690
O.5.6.1 Stanislaus River below Goodwin Dam O-690
O.5.6.2 Stanislaus River at Mouth O-690
O.5.7 San Joaquin River O-699
O.5.7.1 San Joaquin River at Vernalis O-699

O.5.8 Sacramento River Winter-run Chinook Salmon ESU O-704
O.5.8.1 Sacramento River O-704
Spawning and Egg/Alevin Incubation O-704
Juvenile Rearing and Emigration O-710
Adult Upstream Migration and Holding O-720
O.5.8.2 Bay-Delta O-724
Juvenile Rearing and Emigration O-724
O.5.9 Central Valley Spring-run Chinook Salmon ESU O-738
O.5.9.1 Sacramento River O-738
Spawning and Egg/Alevin Incubation O-738
Juvenile–Yearling Rearing and Emigration O-742
Adult Upstream Migration and Holding O-747
O.5.9.2 Clear Creek O-750
Spawning and Egg Incubation O-750
Juvenile–Yearling Rearing and Emigration O-751
Adult Upstream Migration and Holding O-754
O.5.9.3 Bay-Delta O-757
Juvenile–Yearling Rearing and Emigration O-757
O.5.10 California Central Valley Steelhead DPS O-763
O.5.10.1 Sacramento River O-763
Spawning and Egg Incubation O-763
Juvenile Rearing and Emigration O-766
Adult Upstream Migration and Holding O-770
Kelt Emigration O-773
O.5.10.2 Clear Creek O-775
Spawning and Egg Incubation O-775
Juvenile Rearing and Emigration O-777
Adult Upstream Migration and Holding O-780
Kelt Emigration O-781
O.5.10.3 Lower American River O-782
Spawning and Egg Incubation O-782
Juvenile Rearing and Emigration O-786
Adult Upstream Migration and Holding O-788
Kelt Emigration O-791
O.5.10.4 Bay-Delta O-793
Juvenile Rearing and Emigration O-793
O.5.10.5 San Joaquin River O-799
Juvenile Emigration O-799
Adult Upstream Migration and Holding O-799
O.5.10.6 Stanislaus River O-800
Spawning and Egg Incubation O-800
Juvenile Rearing and Emigration O-802
Adult Upstream Migration and Holding O-805
Kelt Emigration O-807
O.5.11 Southern DPS Green Sturgeon O-809
O.5.11.1 Sacramento River O-809

Spawning and Egg Incubation O-809
Larval and Juvenile Rearing and Emigration O-812
Adult Upstream Migration and Holding O-814
O.5.11.2 San Joaquin River O-816
Potential Changes to Green Sturgeon from Seasonal Operations O-816
O.5.11.3 Bay-Delta O-817
Juvenile Rearing and Emigration O-817
Adult Upstream Migration and Holding O-822
O.5.12 Delta Smelt O-822
O.5.12.1 Bay-Delta O-822
Adult Migration and Spawning O-822
Eggs and Larvae O-826
Juveniles O-829
O.5.13 Longfin Smelt O-833
O.5.13.1 Bay Delta O-833
Adult Migration and Spawning O-833
Eggs and Larvae O-837
Juveniles O-840
O.5.14 Fall-run and Late Fall-run Chinook Salmon ESU O-842
O.5.14.1 Sacramento River O-842
Spawning and Egg/Alevin Incubation O-842
Juvenile Rearing and Emigration O-848
Adult Upstream Migration and Holding O-856
O.5.14.2 Clear Creek O-860
Spawning and Egg Incubation O-860
Juvenile Rearing and Emigration O-863
Adult Upstream Migration and Holding O-866
O.5.14.3 Lower American River O-869
Spawning and Egg Incubation O-869
Juvenile Rearing and Emigration O-872
Adult Upstream Migration and Holding O-875
O.5.14.4 San Joaquin River O-878
Potential Changes to Fall-run Chinook Salmon from Seasonal Operations O-878
O.5.14.5 Bay-Delta O-878
Juvenile Rearing and Emigration O-878
O.5.14.6 Stanislaus River O-886
Spawning and Egg Incubation O-886
Juvenile Rearing and Emigration O-887
Adult Upstream Migration and Holding O-890
O.5.15 White Sturgeon O-891
O.5.15.1 Sacramento River O-891
Spawning and Egg Incubation O-891
Larval and Juvenile Rearing and Emigration O-894
Adult Upstream Migration and Holding O-896
O.5.15.2 Lower American River O-898
Potential Changes to White Sturgeon from Seasonal Operations O-898

O.5.15.3 San Joaquin River O-901
Potential Changes to White Sturgeon from Seasonal Operations O-901
O.5.15.4 Bay-Delta O-902
Juvenile Rearing and Emigration O-902
Subadult and Adult Residency O-907
O.5.16 Native Minnows O-907
O.5.16.1 Sacramento River O-907
Sacramento Splittail, Hardhead, and Sacramento Hitch O-907
O.5.16.2 Clear Creek O-911
Hardhead O-911
O.5.16.3 Lower American River O-912
Hardhead and Sacramento Splittail O-912
O.5.16.4 Stanislaus River O-916
Hardhead O-916
O.5.16.5 San Joaquin River O-918
Sacramento Splittail, Hardhead, and Sacramento Hitch O-918
O.5.16.6 Bay-Delta O-920
Hardhead, Sacramento Hitch, and Sacramento Splittail O-920
O.5.17 Pacific Lamprey O-927
O.5.17.1 Trinity River O-927
Spawning and Egg Incubation O-927
Ammocoete Rearing and Emigration O-929
Adult Upstream Migration and Holding O-931
O.5.17.2 Sacramento River O-932
Spawning and Egg Incubation O-932
Ammocoete Rearing and Emigration O-934
O.5.17.3 Clear Creek O-935
Spawning and Egg Incubation O-935
Ammocoete Rearing and Emigration O-937
O.5.17.4 Lower American River O-938
Spawning and Egg Incubation O-938
Ammocoete Rearing and Emigration O-940
O.5.17.5 Stanislaus River O-941
Spawning and Egg Incubation O-941
Ammocoete Rearing and Emigration O-943
O.5.17.6 San Joaquin River O-944
Ammocoete Rearing and Emigration O-944
O.5.17.7 Bay-Delta O-945
Potential Changes to Pacific Lamprey from Seasonal Operations O-945
Potential Changes to Entrainment of Pacific Lamprey O-945
O.5.18 Western River Lamprey O-947
O.5.18.1 Sacramento River O-947
Spawning and Egg Incubation O-947
Ammocoete Rearing and Emigration O-949
O.5.18.2 Lower American River O-950
Spawning and Egg Incubation O-950

Ammocoete Rearing and Emigration O-952
O.5.18.3 Stanislaus River O-953
Spawning and Egg Incubation O-953
Ammocoete Rearing and Emigration O-954
O.5.18.4 San Joaquin River O-956
Ammocoete Rearing and Emigration O-956
O.5.18.5 Bay-Delta O-956
Potential Changes to Western River Lamprey from Seasonal Operations O-957
Potential Changes to Entrainment of Western River Lamprey O-957
O.5.19 Striped Bass O-959
O.5.19.1 Sacramento River O-959
Spawning and Egg Incubation O-959
Larval and Juvenile Rearing and Emigration O-960
O.5.19.2 Lower American River O-962
Adults O-962
Juvenile Rearing O-963
O.5.19.3 Stanislaus River O-965
Spawning and Egg Incubation O-965
Larval and Juvenile Rearing and Emigration O-966
O.5.19.4 San Joaquin River O-968
Potential Changes to Striped Bass from Seasonal Operations O-968
O.5.19.5 Bay-Delta O-968
Potential Changes to Striped Bass from Seasonal Operations O-969
Potential Changes to Entrainment of Striped Bass O-970
O.5.20 American Shad O-972
O.5.20.1 Sacramento River O-972
Spawning and Larval Rearing O-972
Juvenile Rearing and Emigration O-974
O.5.20.2 Lower American River O-975
Spawning and Larval Rearing O-975
Juvenile Rearing and Emigration O-977
O.5.20.3 Stanislaus River O-979
Spawning and Larval Rearing O-979
Juvenile Rearing and Emigration O-980
O.5.20.4 San Joaquin River O-981
Spawning and Larval Rearing O-981
Juvenile Rearing and Emigration O-982
O.5.20.5 Bay-Delta O-983
Potential Changes to American Shad from Seasonal Operations O-983
Potential Changes to Entrainment of American Shad O-985
O.5.21 Threadfin Shad O-986
O.5.21.1 Sacramento River O-986
Potential Changes to Threadfin Shad from Seasonal Operations O-987
O.5.21.2 Lower American River O-988
Potential Changes to Threadfin Shad from Seasonal Operations O-988
O.5.21.3 Stanislaus River O-989

Potential Changes to Threadfin Shad from Seasonal Operations O-990
O.5.21.4 San Joaquin River..... O-990
Potential Changes to Threadfin Shad from Seasonal Operations O-991
O.5.21.5 Bay-Delta..... O-991
Potential Changes to Threadfin Shad from Seasonal Operations O-992
Potential Changes to Entrainment of Threadfin Shad..... O-992
O.5.22 Black Basses O-994
O.5.22.1 Three Micropterus spp..... O-994
Largemouth Bass..... O-994
Smallmouth Bass O-994
Spotted Bass..... O-994
O.5.22.2 Sacramento River O-994
Spawning..... O-994
Non-Spawning Adult O-996
O.5.22.3 Lower American River O-998
Spawning..... O-998
Non-Spawning Adult O-1001
O.5.22.4 Stanislaus River..... O-1004
Spawning..... O-1004
Non-Spawning Adult O-1005
O.5.22.5 San Joaquin River..... O-1006
Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations..... O-1007
O.5.22.6 Bay-Delta..... O-1007
Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations..... O-1007
Potential Changes to Entrainment of Largemouth Bass O-1008
Potential Changes to Entrainment of Smallmouth Bass O-1009
Potential Changes to Entrainment of Spotted Bass..... O-1011
O.5.23 Starry Flounder O-1013
O.5.23.1 Bay-Delta..... O-1013
Potential Changes to Starry Flounder from Seasonal Operations..... O-1013
Potential Changes to Entrainment of Starry Flounder O-1015
O.5.24 Coastal Pelagic Species..... O-1017
O.5.24.1 Potential Changes to Northern Anchovy and Pacific Herring from Seasonal Operations O-1017
O.5.24.2 Potential Changes to Entrainment of Northern Anchovy and Pacific Herring..... O-1017
O.5.25 Upper Klamath-Trinity River Spring-run Chinook Salmon ESU..... O-1018
O.5.25.1 Trinity River O-1018
Spawning and Egg/Alevin Incubation O-1018
Juvenile Rearing and Emigration..... O-1021
Adult Upstream Migration and Holding O-1023
O.5.26 Southern Oregon/Northern California Coast Coho Salmon ESU..... O-1025
O.5.26.1 Trinity River O-1025
Spawning and Egg/Alevin Incubation O-1025

Juvenile Rearing and Emigration O-1030
Adult Upstream Migration and Holding O-1032
O.5.27 Upper Klamath-Trinity River Fall-run Chinook Salmon ESU O-1035
O.5.27.1 Trinity River O-1035
Spawning and Egg/Alevin Incubation O-1035
Juvenile Rearing and Emigration O-1038
Adult Upstream Migration and Holding O-1041
O.5.28 Klamath Mountains Province Steelhead DPS O-1042
O.5.28.1 Trinity River O-1042
Spawning and Egg/Alevin Incubation O-1042
Juvenile Rearing and Emigration O-1045
Adult Upstream Migration and Holding O-1047
O.5.29 Northern DPS Green Sturgeon O-1049
O.5.29.1 Trinity River O-1049
Spawning and Egg Incubation O-1049
Larval and Juvenile Rearing and Emigration O-1050
Adult Upstream Migration and Holding O-1052
O.5.30 Eulachon O-1054
O.5.30.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean O-1054
Spawning and Egg Incubation O-1054
Larval Emigration O-1055
Adult Upstream Migration O-1056
O.5.31 Coastal Cutthroat Trout O-1058
O.5.31.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean O-1058
Spawning and Egg Incubation O-1058
Juvenile Rearing and Emigration O-1059
Adult Holding and Migration O-1060
O.5.32 Brown Trout O-1061
O.5.32.1 Trinity River O-1061
Spawning and Egg Incubation O-1061
Juvenile Rearing and Emigration O-1062
Adult Holding and Migration O-1064
O.5.33 Trinity Reservoir Species O-1065
O.5.33.1 Trinity Reservoir O-1065
Spawning and Egg Incubation O-1065
Larval and Juvenile Rearing and Emigration O-1067
Adult Holding O-1068
O.5.34 Central Valley Reservoir Species O-1070
O.5.34.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations O-1070
Shasta Reservoir O-1070
Whiskeytown Reservoir O-1071
Folsom Reservoir O-1072
New Melones Reservoir O-1073

O.5.35 Delta-Mendota Canal / California Aqueduct Species O-1073
O.5.35.1 Potential Changes to Delta-Mendota Canal/California Aqueduct Species from Seasonal Operations O-1073
O.5.36 San Luis Reservoir Species..... O-1074
O.5.36.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations O-1074
Warmwater Species..... O-1074
O.5.37 Southern Resident Killer Whale O-1074
O.5.37.1 Nearshore Pacific Ocean on the California Coast O-1074
O.6 Alternative 3..... O-1076
O.6.1 Trinity River..... O-1076
O.6.1.1 Trinity River Flows below Lewiston Dam O-1076
O.6.1.2 Trinity Reservoir Storage O-1076
O.6.2 Sacramento River..... O-1079
O.6.2.1 Sacramento River Flows below Keswick Dam O-1079
O.6.2.2 Sacramento River Flows below Red Bluff Diversion Dam O-1079
O.6.2.3 Sacramento River Flows at Wilkins Slough O-1079
O.6.2.4 Sacramento River Flows at Hamilton City..... O-1080
O.6.3 Bay-Delta O-1085
O.6.3.1 Delta X2 ..... O-1085
O.6.3.2 Delta Exports..... O-1085
O.6.3.3 Delta Outflow O-1086
O.6.3.4 Delta OMR O-1086
O.6.3.5 Sacramento River at Rio Vista O-1086
O.6.4 Clear Creek O-1092
O.6.4.1 Clear Creek below Whiskeytown Dam O-1092
O.6.5 Lower American River..... O-1094
O.6.5.1 Lower American River for Folsom Reservoir Storage..... O-1094
O.6.5.2 Lower American River below Nimbus Dam O-1094
O.6.5.3 Lower American River at H Street O-1094
O.6.6 Stanislaus River O-1098
O.6.6.1 Stanislaus River below Goodwin Dam O-1098
O.6.6.2 Stanislaus River at Mouth O-1098
O.6.7 San Joaquin River O-1101
O.6.7.1 San Joaquin River at Vernalis..... O-1101
O.6.8 Sacramento River Winter-run Chinook Salmon ESU..... O-1103
O.6.8.1 Sacramento River O-1103
Spawning and Egg/Alevin Incubation O-1103
Juvenile Rearing and Emigration..... O-1107
Adult Upstream Migration and Holding O-1111
O.6.8.2 Bay-Delta..... O-1113
Juvenile Rearing and Emigration..... O-1113
O.6.9 Central Valley Spring-run Chinook Salmon ESU..... O-1119
O.6.9.1 Sacramento River O-1119
Spawning and Egg/Alevin Incubation O-1119
Juvenile–Yearling Rearing and Emigration O-1121

Adult Upstream Migration and Holding O-1125
O.6.9.2 Clear Creek O-1126
Spawning and Egg Incubation O-1126
Juvenile–Yearling Rearing and Emigration O-1127
Adult Upstream Migration and Holding O-1129
O.6.9.3 Bay-Delta O-1130
Juvenile–Yearling Rearing and Emigration O-1130
O.6.10 California Central Valley Steelhead DPS O-1134
O.6.10.1 Sacramento River O-1134
Spawning and Egg Incubation O-1134
Juvenile Rearing and Emigration O-1136
Adult Upstream Migration and Holding O-1139
Kelt Emigration O-1141
O.6.10.2 Clear Creek O-1142
Spawning and Egg Incubation O-1142
Juvenile Rearing and Emigration O-1144
Adult Upstream Migration and Holding O-1146
Kelt Emigration O-1147
O.6.10.3 Lower American River O-1148
Spawning and Egg Incubation O-1148
Juvenile Rearing and Emigration O-1151
Adult Upstream Migration and Holding O-1152
Kelt Emigration O-1154
O.6.10.4 Bay-Delta O-1156
Juvenile Rearing and Emigration O-1156
O.6.10.5 San Joaquin River O-1158
Juvenile Emigration O-1158
Adult Upstream Migration and Holding O-1159
O.6.10.6 Stanislaus River O-1160
Spawning and Egg Incubation O-1160
Juvenile Rearing and Emigration O-1162
Adult Upstream Migration and Holding O-1164
Kelt Emigration O-1166
O.6.11 Southern DPS Green Sturgeon O-1167
O.6.11.1 Sacramento River O-1167
Spawning and Egg Incubation O-1167
Larval and Juvenile Rearing and Emigration O-1169
Adult Upstream Migration and Holding O-1171
O.6.11.2 San Joaquin River O-1172
Potential Changes to Green Sturgeon from Seasonal Operations O-1172
O.6.11.3 Bay-Delta O-1173
Larval and Juvenile Rearing and Emigration O-1173
Adult Upstream Migration and Holding O-1176
O.6.12 Delta Smelt O-1176
O.6.12.1 Bay-Delta O-1176
Adult Migration and Spawning O-1176

Eggs and Larvae O-1179
Juveniles O-1182
O.6.13 Longfin Smelt O-1185
O.6.13.1 Bay Delta O-1185
Adult Migration and Spawning O-1185
Eggs and Larvae O-1187
Juveniles O-1189
O.6.14 Fall-run and Late Fall-run Chinook Salmon ESU O-1191
O.6.14.1 Sacramento River O-1191
Spawning and Egg/Alevin Incubation O-1191
Juvenile Rearing and Emigration O-1195
Adult Upstream Migration and Holding O-1200
O.6.14.2 Clear Creek O-1202
Spawning and Egg Incubation O-1202
Juvenile Rearing and Emigration O-1204
Adult Upstream Migration and Holding O-1207
O.6.14.3 Lower American River O-1209
Spawning and Egg Incubation O-1209
Juvenile Rearing and Emigration O-1211
Adult Upstream Migration O-1213
O.6.14.4 San Joaquin River O-1214
Potential Changes to Fall-run Chinook Salmon from Seasonal Operations O-1215
O.6.14.5 Bay-Delta O-1215
Juvenile Rearing and Emigration O-1215
O.6.14.6 Stanislaus River O-1218
Spawning and Egg Incubation O-1218
Juvenile Rearing and Emigration O-1220
Adult Upstream Migration and Holding O-1222
O.6.15 White Sturgeon O-1223
O.6.15.1 Sacramento River O-1223
Spawning and Egg Incubation O-1223
Larval and Juvenile Rearing and Emigration O-1224
Adult Upstream Migration and Holding O-1225
O.6.15.2 Lower American River O-1227
Potential Changes to White Sturgeon from Seasonal Operations O-1227
O.6.15.3 San Joaquin River O-1228
Potential Changes to White Sturgeon from Seasonal Operations O-1228
O.6.15.4 Bay-Delta O-1229
Juvenile Rearing and Emigration O-1229
Subadult and Adult Residency O-1230
O.6.16 Native Minnows O-1231
O.6.16.1 Sacramento River O-1231
Sacramento Splittail, Hardhead, and Sacramento Hitch O-1231
O.6.16.2 Clear Creek O-1234
Hardhead O-1234
O.6.16.3 Lower American River O-1235

Hardhead and Sacramento Splittail O-1235
O.6.16.4 Stanislaus River O-1237
Hardhead O-1237
O.6.16.5 San Joaquin River O-1240
Sacramento Splittail, Hardhead, and Sacramento Hitch O-1240
O.6.16.6 Bay-Delta O-1241
Hardhead, Sacramento Hitch, and Sacramento Splittail O-1241
O.6.17 Pacific Lamprey O-1244
O.6.17.1 Trinity River O-1244
Spawning and Egg Incubation O-1244
Ammocoete Rearing and Emigration O-1245
Adult Upstream Migration and Holding O-1246
O.6.17.2 Sacramento River O-1246
Spawning and Egg Incubation O-1246
Ammocoete Rearing and Emigration O-1248
O.6.17.3 Clear Creek O-1249
Spawning and Egg Incubation O-1249
Ammocoete Rearing and Emigration O-1250
O.6.17.4 Lower American River O-1251
Spawning and Egg Incubation O-1251
Ammocoete Rearing and Emigration O-1252
O.6.17.5 Stanislaus River O-1253
Spawning and Egg Incubation O-1253
Ammocoete Rearing and Emigration O-1254
O.6.17.6 San Joaquin River O-1256
Ammocoete Rearing and Emigration O-1256
O.6.17.7 Bay-Delta O-1256
Potential Changes to Pacific Lamprey from Seasonal Operations O-1257
Potential Changes to Entrainment of Pacific Lamprey O-1257
O.6.18 Western River Lamprey O-1258
O.6.18.1 Sacramento River O-1258
Spawning and Egg Incubation O-1258
Ammocoete Rearing and Emigration O-1259
O.6.18.2 Lower American River O-1260
Spawning and Egg Incubation O-1260
Ammocoete Rearing and Emigration O-1261
O.6.18.3 Stanislaus River O-1262
Spawning and Egg Incubation O-1262
Ammocoete Rearing and Emigration O-1263
O.6.18.4 San Joaquin River O-1265
Ammocoete Rearing and Emigration O-1265
O.6.18.5 Bay-Delta O-1265
Potential Changes to Western River Lamprey from Seasonal Operations O-1266
Potential Changes to Entrainment of Western River Lamprey O-1266
O.6.19 Striped Bass O-1267
O.6.19.1 Sacramento River O-1267

Spawning and Egg Incubation O-1267
Laval and Juvenile Rearing and Emigration O-1268
O.6.19.2 Lower American River O-1269
Adults O-1269
Juvenile Rearing O-1270
O.6.19.3 Stanislaus River O-1271
Spawning and Egg Incubation O-1271
Laval and Juvenile Rearing and Emigration O-1272
O.6.19.4 San Joaquin River O-1274
Potential Changes to Striped Bass from Seasonal Operations O-1274
O.6.19.5 Bay-Delta O-1274
Potential Changes to Striped Bass from Seasonal Operations O-1275
Potential Changes to Striped Bass from Seasonal Operations O-1275
Potential Changes to Entrainment of Striped Bass O-1275
O.6.20 American Shad O-1276
O.6.20.1 Sacramento River O-1276
Spawning and Larval Rearing O-1276
Juvenile Rearing and Emigration O-1277
O.6.20.2 Lower American River O-1278
Spawning and Larval Rearing O-1278
Juvenile Rearing and Emigration O-1279
O.6.20.3 Stanislaus River O-1280
Spawning and Larval Rearing O-1280
Juvenile Rearing and Emigration O-1281
O.6.20.4 San Joaquin River O-1282
Spawning and Larval Rearing O-1282
Juvenile Rearing and Emigration O-1283
O.6.20.5 Bay-Delta O-1284
Potential Changes to American Shad from Seasonal Operations O-1284
Potential Changes to Entrainment of American Shad O-1285
O.6.21 Threadfin Shad O-1285
O.6.21.1 Sacramento River O-1285
Potential Changes to Threadfin Shad from Seasonal Operations O-1285
O.6.21.2 Lower American River O-1286
Potential Changes to Threadfin Shad from Seasonal Operations O-1286
O.6.21.3 Stanislaus River O-1287
Potential Changes to Threadfin Shad from Seasonal Operations O-1287
O.6.21.4 San Joaquin River O-1288
Potential Changes to Threadfin Shad from Seasonal Operations O-1289
O.6.21.5 Bay-Delta O-1289
Potential Changes to Threadfin Shad from Seasonal Operations O-1289
Potential Changes to Entrainment of Threadfin Shad O-1290
O.6.22 Black Basses O-1290
O.6.22.1 Three Micropterus spp O-1290
Largemouth Bass O-1290
Smallmouth Bass O-1291

Spotted Bass O-1291
O.6.22.2 Sacramento River O-1291
Spawning O-1291
Non-Spawning Adult O-1292
O.6.22.3 Lower American River O-1294
Spawning O-1294
Non-Spawning Adult O-1295
O.6.22.4 Stanislaus River O-1297
Spawning O-1297
Non-Spawning Adult O-1298
O.6.22.5 San Joaquin River O-1299
Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations O-1299
O.6.22.6 Bay-Delta O-1300
Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations O-1300
Potential Changes to Entrainment of Largemouth Bass O-1300
Potential Changes to Entrainment of Smallmouth Bass O-1301
Potential Changes to Entrainment of Spotted Bass O-1301
O.6.23 Starry Flounder O-1302
O.6.23.1 Bay-Delta O-1302
Potential Changes to Starry Flounder from Seasonal Operations O-1303
Potential Changes to Entrainment of Starry Flounder O-1303
O.6.24 Coastal Pelagic Species O-1304
O.6.24.1 Potential Changes to Northern Anchovy and Pacific Herring from Seasonal Operations O-1304
O.6.24.2 Potential Changes to Entrainment of Northern Anchovy and Pacific Herring O-1304
O.6.25 Southern Oregon/Northern California Coast Coho Salmon ESU O-1305
O.6.25.1 Trinity River O-1305
Spawning and Egg/Alevin Incubation O-1305
Juvenile Rearing and Emigration O-1306
Adult Upstream Migration and Holding O-1309
O.6.26 Upper Klamath-Trinity River Spring-run Chinook Salmon ESU O-1310
O.6.26.1 Trinity River O-1310
Spawning and Egg/Alevin Incubation O-1310
Juvenile Rearing and Emigration O-1311
Adult Upstream Migration and Holding O-1314
O.6.27 Upper Klamath-Trinity River Fall-run Chinook Salmon ESU O-1315
O.6.27.1 Trinity River O-1315
Spawning and Egg/Alevin Incubation O-1315
Juvenile Rearing and Emigration O-1317
Adult Upstream Migration and Holding O-1319
O.6.28 Klamath Mountains Province Steelhead DPS O-1320
O.6.28.1 Trinity River O-1320
Spawning and Egg/Alevin Incubation O-1320

Juvenile Rearing and Emigration O-1321
Adult Upstream Migration and Holding O-1323
O.6.29 Northern DPS Green Sturgeon O-1326
O.6.29.1 Trinity River O-1326
Spawning and Egg Incubation O-1326
Larval and Juvenile Rearing and Emigration O-1326
Adult Upstream Migration and Holding O-1327
O.6.30 Eulachon O-1328
O.6.30.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean O-1328
Spawning and Egg Incubation O-1328
Larval Emigration O-1329
Adult Upstream Migration O-1329
O.6.31 Coastal Cutthroat Trout O-1330
O.6.31.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean O-1330
Spawning and Egg Incubation O-1330
Juvenile Rearing and Emigration O-1331
Adult Holding and Migration O-1332
O.6.32 Brown Trout O-1333
O.6.32.1 Trinity River O-1333
Spawning and Egg Incubation O-1333
Juvenile Rearing and Emigration O-1334
Adult Holding and Migration O-1334
O.6.33 Trinity Reservoir Species O-1335
O.6.33.1 Trinity Reservoir O-1335
Spawning and Egg Incubation O-1335
Larval and Juvenile Rearing and Emigration O-1336
Adult Holding O-1337
O.6.34 Central Valley Reservoir Species O-1338
O.6.34.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations O-1338
Shasta Reservoir O-1338
Whiskeytown Reservoir O-1339
Folsom Reservoir O-1339
New Melones Reservoir O-1340
O.6.35 Delta-Mendota Canal/California Aqueduct Species O-1340
O.6.35.1 Potential Changes to Delta-Mendota Canal/California Aqueduct Species from Seasonal Operations O-1340
O.6.36 San Luis Reservoir Species O-1341
O.6.36.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations O-1341
Warmwater Species O-1341
O.6.37 Southern Resident Killer Whale O-1341
O.6.37.1 Nearshore Pacific Ocean on the California Coast O-1341
O.7 Alternative 4 ..... O-1342

O.7.1 Trinity River O-1342
O.7.1.1 Trinity River Flows below Lewiston Dam O-1342
O.7.1.2 Trinity Reservoir storage O-1342
O.7.2 Sacramento River O-1345
O.7.2.1 Sacramento River Flows below Keswick Dam O-1345
O.7.2.2 Sacramento River Flows below Red Bluff Diversion Dam O-1346
O.7.2.3 Sacramento River Flows at Wilkins Slough O-1346
O.7.2.4 Sacramento River Flows at Hamilton City O-1346
O.7.3 Bay-Delta O-1351
O.7.3.1 Delta Exports O-1351
O.7.3.2 Delta X2 ..... O-1351
O.7.3.3 Delta Exports O-1351
O.7.3.4 Delta Outflow O-1351
O.7.3.5 Delta OMR O-1351
O.7.3.6 Sacramento River at Rio Vista O-1352
O.7.4 Clear Creek O-1358
O.7.4.1 Clear Creek below Whiskeytown Dam O-1358
O.7.5 Lower American River O-1360
O.7.5.1 Lower American River for Folsom Reservoir Storage O-1361
O.7.5.2 Lower American River below Nimbus Dam O-1361
O.7.5.3 Lower American River at H Street O-1361
O.7.6 Stanislaus River O-1365
O.7.6.1 Stanislaus River below Goodwin Dam O-1365
O.7.6.2 Stanislaus River at Mouth O-1365
O.7.7 San Joaquin River O-1368
O.7.7.1 San Joaquin River at Vernalis O-1368
O.7.8 Sacramento River Winter-run Chinook Salmon ESU O-1370
O.7.8.1 Sacramento River O-1370
Spawning and Egg/Alevin Incubation O-1370
Juvenile Rearing and Emigration O-1374
Adult Upstream Migration and Holding O-1378
O.7.8.2 Bay-Delta O-1379
Juvenile Rearing and Emigration O-1379
O.7.9 Central Valley Spring-run Chinook Salmon ESU O-1384
O.7.9.1 Sacramento River O-1384
Spawning and Egg/Alevin Incubation O-1384
Juvenile–Yearling Rearing and Emigration O-1386
Adult Upstream Migration and Holding O-1390
O.7.9.2 Clear Creek O-1391
Spawning and Egg Incubation O-1391
Juvenile–Yearling Rearing and Emigration O-1392
Adult Upstream Migration and Holding O-1394
O.7.9.3 Bay-Delta O-1395
Juvenile–Yearling Rearing and Emigration O-1395
O.7.10 California Central Valley Steelhead DPS O-1398
O.7.10.1 Sacramento River O-1398

Spawning and Egg Incubation O-1398
Juvenile Rearing and Emigration O-1401
Adult Upstream Migration and Holding O-1404
Kelt Emigration O-1405
O.7.10.2 Clear Creek O-1407
Spawning and Egg Incubation O-1407
Juvenile Rearing and Emigration O-1408
Adult Upstream Migration and Holding O-1410
Kelt Emigration O-1411
O.7.10.3 Lower American River O-1412
Spawning and Egg Incubation O-1412
Juvenile Rearing and Emigration O-1415
Adult Upstream Migration and Holding O-1416
Kelt Emigration O-1418
O.7.10.4 Bay-Delta O-1419
Juvenile Rearing and Emigration O-1419
O.7.10.5 San Joaquin River O-1422
Juvenile Emigration O-1422
Adult Upstream Migration and Holding O-1423
O.7.10.6 Stanislaus River O-1423
Spawning and Egg Incubation O-1423
Juvenile Rearing and Emigration O-1425
Adult Upstream Migration and Holding O-1428
Kelt Emigration O-1429
O.7.11 Southern DPS Green Sturgeon O-1431
O.7.11.1 Sacramento River O-1431
Spawning and Egg Incubation O-1431
Larval and Juvenile Rearing and Emigration O-1432
Adult Upstream Migration and Holding O-1434
O.7.11.2 San Joaquin River O-1435
Potential Changes to White Sturgeon from Seasonal Operations O-1435
O.7.11.3 Bay-Delta O-1436
Larval and Juvenile Rearing and Emigration O-1436
Adult Upstream Migration and Holding O-1438
O.7.12 Delta Smelt O-1438
O.7.12.1 Bay-Delta O-1438
Adult Migration and Spawning O-1438
Eggs and Larvae O-1441
Juveniles O-1444
O.7.13 Longfin Smelt O-1447
O.7.13.1 Bay Delta O-1447
Adult Migration and Spawning O-1447
Eggs and Larvae O-1449
Juveniles O-1451
O.7.14 Fall-run and Late Fall-run Chinook Salmon ESU O-1453
O.7.14.1 Sacramento River O-1453

Spawning and Egg/Alevin Incubation O-1453
Juvenile Rearing and Emigration O-1457
Adult Upstream Migration and Holding O-1462
O.7.14.2 Clear Creek O-1464
Spawning and Egg Incubation O-1464
Juvenile Rearing and Emigration O-1466
Adult Upstream Migration and Holding O-1469
O.7.14.3 Lower American River O-1471
Spawning and Egg Incubation O-1471
Juvenile Rearing and Emigration O-1473
Adult Upstream Migration and Holding O-1475
O.7.14.4 San Joaquin River O-1476
Potential Changes to Fall-run Chinook Salmon from Seasonal Operations . O-1476
O.7.14.5 Bay-Delta O-1476
Juvenile Rearing and Emigration O-1476
O.7.14.6 Stanislaus River O-1480
Spawning and Egg Incubation O-1480
Juvenile Rearing and Emigration O-1481
Adult Upstream Migration and Holding O-1483
O.7.15 White Sturgeon O-1485
O.7.15.1 Sacramento River O-1485
Spawning and Egg Incubation O-1485
Larval and Juvenile Rearing and Emigration O-1486
Adult Upstream Migration and Holding O-1487
O.7.15.2 Lower American River O-1488
Potential Changes to White Sturgeon from Seasonal Operations O-1488
O.7.15.3 San Joaquin River O-1489
Potential Changes to White Sturgeon from Seasonal Operations O-1489
O.7.15.4 Bay-Delta O-1490
Juvenile Rearing and Emigration O-1490
Subadult and Adult Residency O-1491
O.7.16 Native Minnows O-1492
O.7.16.1 Sacramento River O-1492
Sacramento Splittail, Hardhead, and Sacramento Hitch O-1492
O.7.16.2 Clear Creek O-1494
Hardhead O-1494
O.7.16.3 Lower American River O-1495
Hardhead and Sacramento Splittail O-1495
O.7.16.4 Stanislaus River O-1498
Hardhead O-1498
O.7.16.5 San Joaquin River O-1500
Sacramento Splittail, Hardhead, and Sacramento Hitch O-1500
O.7.16.6 Bay-Delta O-1501
Hardhead, Sacramento Hitch, and Sacramento Splittail O-1501
O.7.17 Pacific Lamprey O-1504
O.7.17.1 Trinity River O-1504

Spawning and Egg Incubation O-1504
Ammocoete Rearing and Emigration..... O-1505
Adult Upstream Migration and Holding O-1505
O.7.17.2 Sacramento River O-1506
Spawning and Egg Incubation O-1506
Ammocoete Rearing and Emigration..... O-1507
O.7.17.3 Clear Creek..... O-1508
Spawning and Egg Incubation O-1508
Ammocoete Rearing and Emigration..... O-1509
O.7.17.4 Lower American River O-1510
Spawning and Egg Incubation O-1510
Ammocoete Rearing and Emigration..... O-1511
O.7.17.5 Stanislaus River..... O-1513
Spawning and Egg Incubation O-1513
Ammocoete Rearing and Emigration..... O-1514
O.7.17.6 San Joaquin River..... O-1515
Ammocoete Rearing and Emigration..... O-1515
O.7.17.7 Bay-Delta..... O-1515
Potential Changes to Pacific Lamprey from Seasonal Operations O-1516
Potential Changes to Entrainment of Pacific Lamprey..... O-1516
O.7.18 Western River Lamprey O-1517
O.7.18.1 Sacramento River O-1517
Spawning and Egg Incubation O-1517
Ammocoete Rearing and Emigration..... O-1518
O.7.18.2 Lower American River O-1519
Spawning and Egg Incubation O-1519
Ammocoete Rearing and Emigration..... O-1520
O.7.18.3 Stanislaus River..... O-1521
Spawning and Egg Incubation O-1521
Ammocoete Rearing and Emigration..... O-1522
O.7.18.4 San Joaquin River..... O-1523
Ammocoete Rearing and Emigration..... O-1523
O.7.18.5 Bay-Delta..... O-1524
Potential Changes to Western River Lamprey from Seasonal Operations.... O-1524
Potential Changes to Entrainment of Western River Lamprey O-1525
O.7.19 Striped Bass O-1525
O.7.19.1 Sacramento River O-1525
Spawning and Egg Incubation O-1525
Larval and Juvenile Rearing and Emigration..... O-1526
O.7.19.2 Lower American River O-1527
Adults..... O-1527
Juvenile Rearing..... O-1528
O.7.19.3 Stanislaus River..... O-1529
Spawning and Egg Incubation O-1529
Larval and Juvenile Rearing and Emigration..... O-1530
O.7.19.4 San Joaquin River..... O-1531

Potential Changes to Striped Bass from Seasonal Operations O-1532
O.7.19.5 Bay-Delta O-1532
Potential Changes to Striped Bass from Seasonal Operations O-1533
Potential Changes to Entrainment of Striped Bass O-1533
O.7.20 American Shad O-1534
O.7.20.1 Sacramento River O-1534
Spawning and Larval Rearing O-1534
Juvenile Rearing and Emigration O-1535
O.7.20.2 Lower American River O-1536
Spawning and Larval Rearing O-1536
Juvenile Rearing and Emigration O-1537
O.7.20.3 Stanislaus River O-1538
Spawning and Larval Rearing O-1538
Juvenile Rearing and Emigration O-1539
O.7.20.4 San Joaquin River O-1540
Spawning and Larval Rearing O-1540
Juvenile Rearing and Emigration O-1541
O.7.20.5 Bay-Delta O-1542
Potential Changes to American Shad from Seasonal Operations O-1542
Potential Changes to Entrainment of American Shad O-1542
O.7.21 Threadfin Shad O-1543
O.7.21.1 Sacramento River O-1543
Potential Changes to Threadfin Shad from Seasonal Operations O-1543
O.7.21.2 Lower American River O-1544
Potential Changes to Threadfin Shad from Seasonal Operations O-1544
O.7.21.3 Stanislaus River O-1545
Potential Changes to Threadfin Shad from Seasonal Operations O-1545
O.7.21.4 San Joaquin River O-1546
Potential Changes to Threadfin Shad from Seasonal Operations O-1546
O.7.21.5 Bay-Delta O-1547
Potential Changes to Threadfin Shad from Seasonal Operations O-1547
Juvenile Rearing and Non-Spawning Adults O-1547
O.7.22 Black Basses O-1548
O.7.22.1 Three Micropterus spp. O-1548
Largemouth Bass O-1549
Smallmouth Bass O-1549
Spotted Bass O-1549
O.7.22.2 Sacramento River O-1549
Spawning O-1549
Non-Spawning Adult O-1550
O.7.22.3 Lower American River O-1552
Spawning O-1552
Non-Spawning Adult O-1553
O.7.22.4 Stanislaus River O-1554
Spawning O-1554
Non-Spawning Adult O-1555

O.7.22.5 San Joaquin River O-1557
Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations O-1557
O.7.22.6 Bay-Delta O-1557
Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations O-1558
Potential Changes to Entrainment of Largemouth Bass O-1558
Potential Changes to Entrainment of Smallmouth Bass O-1558
Potential Changes to Entrainment of Spotted Bass O-1559
O.7.23 Starry Flounder O-1560
O.7.23.1 Bay-Delta O-1560
Potential Changes to Starry Flounder from Seasonal Operations O-1560
Potential Changes to Entrainment of Starry Flounder O-1560
O.7.24 Coastal Pelagic Species O-1561
O.7.24.1 Potential Changes to Northern Anchovy and Pacific Herring from Seasonal Operations O-1561
O.7.24.2 Potential Changes to Entrainment of Northern Anchovy and Pacific Herring O-1561
O.7.25 Southern Oregon/Northern California Coast Coho salmon ESU O-1562
O.7.25.1 Trinity River O-1562
Spawning and Egg/Alevin Incubation O-1562
Juvenile Rearing and Emigration O-1563
Adult Upstream Migration and Holding O-1565
O.7.26 Upper Klamath-Trinity River Spring-run Chinook Salmon ESU O-1566
O.7.26.1 Trinity River O-1566
Spawning and Egg/Alevin Incubation O-1566
Juvenile Rearing and Emigration O-1567
Adult Upstream Migration and Holding O-1569
O.7.27 Upper Klamath-Trinity River Fall-run Chinook Salmon ESU O-1570
O.7.27.1 Trinity River O-1570
Spawning and Egg/Alevin Incubation O-1570
Juvenile Rearing and Emigration O-1571
Adult Upstream Migration and Holding O-1573
O.7.28 Klamath Mountains Province Steelhead DPS O-1573
O.7.28.1 Trinity River O-1573
Spawning and Egg/Alevin Incubation O-1574
Juvenile Rearing and Emigration O-1575
Adult Upstream Migration and Holding O-1576
O.7.29 Northern DPS Green Sturgeon O-1579
O.7.29.1 Trinity River O-1579
Spawning and Egg Incubation O-1579
Larval and Juvenile Rearing and Emigration O-1579
Adult Upstream Migration and Holding O-1580
O.7.30 Eulachon O-1581
O.7.30.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean O-1581

Spawning and Egg Incubation O-1581
Larval Emigration O-1582
Adult Upstream Migration O-1582
O.7.31 Coastal Cutthroat Trout O-1583
O.7.31.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean O-1583
Spawning and Egg Incubation O-1583
Juvenile Rearing and Emigration O-1584
Adult Holding and Migration O-1585
O.7.32 Brown Trout O-1586
O.7.32.1 Trinity River O-1586
Spawning and Egg Incubation O-1586
Juvenile Rearing and Emigration O-1586
Adult Holding and Migration O-1587
O.7.33 Trinity Reservoir Species O-1588
O.7.33.1 Trinity Reservoir O-1588
Spawning and Egg Incubation O-1588
Larval and Juvenile Rearing and Emigration O-1589
Adult Holding O-1589
O.7.34 Central Valley Reservoir Species O-1590
O.7.34.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations O-1590
Shasta Reservoir O-1590
Whiskeytown Reservoir O-1591
Folsom Reservoir O-1591
New Melones Reservoir O-1592
O.7.35 Delta-Mendota Canal / California Aqueduct Species O-1592
O.7.35.1 Potential Changes to Delta-Mendota Canal/California Aqueduct Species from Seasonal Operations O-1592
O.7.36 San Luis Reservoir Species O-1593
O.7.36.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations O-1593
Warmwater Species O-1593
O.7.37 Southern Resident Killer Whale O-1593
O.7.37.1 Nearshore Pacific Ocean on the California Coast O-1593

O.8 Summary of Impacts O-1595
O.9 Mitigation Measures O-1657
O.9.1 Alternative 1 ..... O-1657
O.9.1.1 Avoidance and Minimization Measures O-1657
O.9.1.2 Additional Mitigation O-1658
O.9.2 Alternative 2 ..... O-1658
O.9.2.1 Avoidance and Minimization Measures O-1658

O.9.2.2 Additional Mitigation O-1666
O.9.3 Alternative 3 ..... O-1667
O.9.3.1 Avoidance and Minimization Measures O-1667
Water Temperature Clear Creek O-1667
Minimum Instream Flows (Minimum Release Requirements) American River O-1667
Old and Middle River Reverse Flows O-1667
Winter and Spring Delta Outflow O-1667
Delta Smelt Summer and Fall Habitat O-1668
Drought O-1668
O.9.3.2 Additional Mitigation O-1668
O.9.4 Alternative 4 ..... O-1668
O.9.4.1 Avoidance and Minimization Measures O-1668
Water Temperature Management O-1668
Minimum Instream Flows (Minimum Release Requirement) American River O-1669
Old and Middle River Flow Management O-1669
O.9.4.2 Additional Mitigation O-1672
O.10 Cumulative Impacts O-1672
O.10.1 Sacramento River O-1673
O.10.1.1 Anadromous Salmonids O-1674
No Action Alternative O-1674
Alternatives 1–4 ..... O-1674
O.10.1.2 Green and White Sturgeon O-1676
No Action Alternative O-1676
Alternative 1–4 ..... O-1676
O.10.1.3 Other Focal Fish Species O-1677
O.10.2 Clear Creek O-1677
O.10.2.1 Anadromous Salmonids O-1678
No Action Alternative O-1678
Alternatives 1–4 ..... O-1678
O.10.2.2 Other Focal Fish Species O-1679
O.10.3 Lower American River O-1679
O.10.3.1 Anadromous Salmonids O-1680
No Action Alternative O-1680
Alternatives 1–4 ..... O-1680
O.10.3.2 Other Focal Fish Species O-1681
O.10.4 Bay-Delta O-1681
O.10.4.1 Osmerids O-1681
No Action Alternative O-1681
Alternatives 1–4 ..... O-1682
O.10.4.2 Anadromous Salmonids O-1682
No Action Alternative O-1682
Alternatives 1–4 ..... O-1682
O.10.4.3 Green and White Sturgeon O-1683
No Action Alternative O-1683

Alternatives 1–4 ..... O-1683
O.10.4.4 Other Focal Fish Species O-1683
O.10.5 San Joaquin River O-1684
O.10.6 Stanislaus River O-1684
O.10.6.1 Anadromous Salmonids O-1685
No Action Alternative O-1685
Alternatives 1–4 ..... O-1685
O.10.6.2 Other Focal Fish Species O-1686
O.10.7 Trinity River O-1686
O.10.7.1 Anadromous Salmonids O-1687
No Action Alternative O-1687
Alternatives 1–4 ..... O-1687
O.10.7.2 Green and White Sturgeon O-1687
No Action Alternative O-1687
Alternatives 1–4 ..... O-1687
O.10.7.3 Other Focal Species O-1687
No Action Alternative O-1688
Alternatives 1–4 ..... O-1688
O.10.8 Nearshore Pacific Ocean of the California Coast O-1688
O.10.8.1 Southern Resident Killer Whale O-1688
O.10 References O-1689
O.10.1 Literature Cited O-1689
O.10.2 Personal Communications O-1767
O.10.3 Federal Register Notices O-1767
O.10.4 Water Rights Orders O-1768

Tables

Table O-1. Focal Aquatic Species by Region of Occurrence O-2

Table O-2. Recreational Angler Catch as Reported in Fall Creel Surveys of the Lower Klamath River, 1998–2022 ..... O-23

Table O-3. Recreational Angler Catch as Reported in Spring Creel Surveys of the Lower Klamath River, 2017–2022 ..... O-23

Table O-4. Harvest and Abundance Indices for Adult Fall-run Chinook Salmon O-53

Table O-5. All Steelhead Catch and Recorded Trips Within the American River and Tributaries Location Code From 2015–2019 ..... O-81

Table O-6. Stanislaus River Minimum Fish Flow Schedule During Critically Dry Water Year Types O-84

Table O-7. Stanislaus River Minimum Fish Flow Schedule During Dry Water Year Types O-85

Table O-8. Stanislaus River Minimum Fish Flow Schedule During Below Normal Water Year Types O-87

Table O-9. Stanislaus River Minimum Fish Flow Schedule During Wet Water Year Types O-88

Table O-10. Criterion and Temperature Compliance Location O-91

Table O-11. Water Temperature Objectives for the 40-Mile Reach from Lewiston Dam Downstream to the Confluence with the North Fork Trinity River O-229

Table O-12. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston for the No Action Alternative, Alternative 1 and Differences between Them O-248

Table O-13. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir Storage for the No Action Alternative, Alternative 1 and Differences between Them O-249

Table O-14. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 1 and Differences between Them O-255

Table O-15. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 1 and Differences between Them O-256

Table O-16. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 1 and Differences between Them O-257

Table O-17. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 1 and Differences between Them O-258

Table O-18. CalSim 3 Estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 1 and Differences between Them O-261

Table O-19. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 1 and Differences between Them O-262

Table O-20. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 1 and Differences between Them O-263

Table O-21. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 1 and Differences between Them O-264

Table O-22. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River at Rio Vista for No Action Alternative, Alternative 1 and Differences between Them O-265

Table O-23. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 1 and Differences between Them O-267

Table O-24. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 1 and Differences between Them O-270

Table O-25. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for American River below Nimbus Dam for No Action Alternative, Alternative 1 and Differences between Them O-271

Table O-26. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the American River at H street for No Action Alternative, Alternative 1 and Differences between Them O-272

Table O-27. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 1 and Differences between Them O-274

Table O-28. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 1 and Differences between Them O-275

Table O-29. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 1 and Differences between Them O-277

Table O-30. Summary Metrics by Alternative from the OBAN Model: Spawner Abundance, Probability of Quasi-Extinction, Egg to Fry Survival, and Delta Survival O-280

Table O-31. Summary of Results for Water Temperature Analyses for Winter-run Chinook Salmon Spawning and Egg/Alevin Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-283

Table O-32. Summary of Results for Water Temperature Analyses for Winter-run Chinook Salmon Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-288

Table O-33. Summary of Results for Water Temperature Analyses for Winter-run Chinook Salmon Adult Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-291

Table O-34. Predicted Average Monthly Loss of Length-at-Date Winter-run Chinook Salmon at Banks by Water Year Type for all Months With Predicted Non-Zero Average Monthly Loss O-297

Table O-35. Predicted Average Monthly Loss of Length-at-Date Winter-run Chinook Salmon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-297

Table O-36. Predicted Average Monthly Loss of Genetic Winter-run Chinook Salmon at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-298

Table O-37. Predicted Average Monthly Loss of Genetic Winter-run Chinook Salmon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-298

Table O-38. Predicted Average Monthly Salvage of Juvenile Winter-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type, December–April O-299

Table O-39. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Spawning and Egg/Alevin Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-307

Table O-40. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Juvenile to Yearling Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-311

Table O-41. Summary of Results for Water Temperature Analyses for spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-314

Table O-42. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Spawning and Egg/Alevin Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-316

Table O-43. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Juvenile and Yearling Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-319

Table O-44. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Upstream Migration and Holding in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-321

Table O-45. Predicted Average Monthly Loss of LAD SR at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-323

Table O-46. Predicted Average Monthly Loss of LAD SR at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-323

Table O-47. Predicted Average Monthly Salvage of Juvenile Spring-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type, March–June..... O-324

Table O-48. Summary of Results for Water Temperature Analyses for Steelhead Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-327

Table O-49. Summary of Results for Water Temperature Analyses for Steelhead Juvenile Rearing and Emigration in the Sacramento River for each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-331

Table O-50. Summary of Results for Water Temperature Analyses for Steelhead Adult Upstream Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-334

Table O-51. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Kelt Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-337

Table O-52. Summary of Results for Water Temperature Analyses for Steelhead Spawning and Egg Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-340

Table O-53. Summary of Results for Water Temperature Analyses for Steelhead Juvenile Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-343

Table O-54. Summary of Results for Water Temperature Analyses for Steelhead Adult Upstream Migration and Holding in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-345

Table O-55. Summary of Results for Water Temperature Analyses for Steelhead Kelt Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-347

Table O-56. Summary of Results for Water Temperature Analyses for Steelhead Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-350

Table O-57. Summary of Results for Water Temperature Analyses for Steelhead Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-353

Table O-58. Summary of Results for Water Temperature Analyses for Adult Steelhead Upstream Migration and Holding for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-355

Table O-59. Summary of Results for Water Temperature Analyses for Steelhead Kelt Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-358

Table O-60. Predicted Average Monthly Loss of Steelhead at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-360

Table O-61. Predicted Average Monthly Loss of Steelhead at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-361

Table O-62. Predicted Average Monthly Salvage of Juvenile Steelhead at the Delta Fish Collection Facilities by Water Year Type, December–June O-361

Table O-63. Summary of Results for Water Temperature Analyses for Steelhead Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-366

Table O-64. Summary of Results for Water Temperature Analyses for Steelhead Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-369

Table O-65. Summary of Results for Water Temperature Analyses for Adult Steelhead Upstream Migration and Holding for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-372

Table O-66. Summary of Results for Water Temperature Analyses for Steelhead Kelt Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-374

Table O-67. Summary of Results for Water Temperature Analyses for Green Sturgeon Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-377

Table O-68. Summary of Results for Water Temperature Analyses for Green Sturgeon Larval and Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-380

Table O-69. Summary of Results for Water Temperature Analyses for Green Sturgeon Adult Upstream Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-382

Table O-70. Year-Class Strength of White Sturgeon (Percent Difference from No Action Alternative), Based on April–May Regression With Delta Outflow O-385

Table O-71. Year-Class Strength of White Sturgeon (Percent Difference from No Action Alternative), Based on March–July Regression With Delta Outflow O-386

Table O-72. Predicted Average Monthly Loss of GST at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-387

Table O-73. Predicted Average Monthly Loss of GST at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-387

Table O-74. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-410

Table O-75. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-413

Table O-76. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-416

Table O-77. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-420

Table O-78. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Adult Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-423

Table O-79. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Adult Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-425

Table O-80. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-427

Table O-81. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-429

Table O-82. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Juvenile Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-431

Table O-83. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Juvenile Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-433

Table O-84. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Adult Upstream Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-435

Table O-85. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Adult Upstream Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-436

Table O-86. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-439

Table O-87. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-442

Table O-88. Summary of Results for Water Temperature Analyses for Adult Fall-run Chinook Salmon Upstream Migration and Holding for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-445

Table O-89. Predicted Average Monthly Loss of Fall-run Chinook Salmon at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-448

Table O-90. Predicted Average Monthly Loss of Fall-run Chinook Salmon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-448

Table O-91. Predicted Average Monthly Loss of Late Fall-run Chinook Salmon at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-449

Table O-92. Predicted Average Monthly Loss of Late Fall-run Chinook Salmon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-450

Table O-93. Summary of Results for Water Temperature Analyses for fall-run Chinook salmon spawning and egg incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-452

Table O-94. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-455

Table O-95. Summary of Results for Water Temperature Analyses for Adult Fall-run Chinook Salmon Upstream Migration and Holding for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-457

Table O-96. Summary of Results for Water Temperature Analyses for White Sturgeon Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-459

Table O-97. Summary of Results for Water Temperature Analyses for White Sturgeon Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-461

Table O-98. Summary of Results for Water Temperature Analyses for White Sturgeon Adult Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-463

Table O-99. Summary of Results for Water Temperature Analyses for Non-spawning Adult White Sturgeon for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-464

Table O-100. Predicted Average Monthly Loss of White Sturgeon at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss ... O-467

Table O-101. Predicted Average Monthly Loss of White Sturgeon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss ... O-468

Table O-102. Summary of Results for Water Temperature Analyses for Native Minnow Spawning and Non-spawning Adults in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-471

Table O-103. Summary of Results for Water Temperature Analyses for Native Minnow Spawning and Non-spawning Adults in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-474

Table O-104. Summary of Results for Water Temperature Analyses for Spawning Adult Hardhead for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-477

Table O-105. Summary of Results for Water Temperature Analyses for Spawning and Non-spawning Adult Hardhead for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-479

Table O-106. Predicted Average Monthly Loss of Sacramento Splittail at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-484

Table O-107. Predicted Average Monthly Loss of Sacramento Splittail at Jones by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss . O-484

Table O-108. Predicted Average Monthly Loss of Hardhead at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-485

Table O-109. Predicted Average Monthly Loss of Hardhead at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-485

Table O-110. Predicted Average Monthly Loss of Sacramento Hitch at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-486

Table O-111. Predicted Average Monthly Loss of Sacramento Hitch at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-487

Table O-112. Summary of Results for Water Temperature Analyses for Pacific Lamprey Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-491

Table O-113. Summary of Results for Water Temperature Analyses for Pacific Lamprey Ammocoete Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-492

Table O-114. Summary of Results for Water Temperature Analyses for Pacific Lamprey Spawning and Egg Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-494

Table O-115. Summary of Results for Water Temperature Analyses for Pacific Lamprey Ammocoete Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-495

Table O-116. Summary of Results for Water Temperature Analyses for Pacific Lamprey Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-497

Table O-117. Summary of Results for Water Temperature Analyses for Pacific Lamprey Ammocoete Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-499

Table O-118. Summary of Results for Water Temperature Analyses for Pacific Lamprey Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-500

Table O-119. Summary of Results for Water Temperature Analyses for Pacific Lamprey Ammocoete Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-502

Table O-120. Predicted Average Monthly Loss of Pacific Lamprey at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss ... O-505

Table O-121. Predicted Average Monthly Loss of Pacific Lamprey at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss ... O-505

Table O-122. Summary of Results for Water Temperature Analyses for Western River Lamprey Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-507

Table O-123. Summary of Results for Water Temperature Analyses for Western River Lamprey Ammocoete Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-509

Table O-124. Summary of Results for Water Temperature Analyses for Western River Lamprey Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-511

Table O-125. Summary of Results for Water Temperature Analyses for Western River Lamprey Ammocoete Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-513

Table O-126. Summary of Results for Water Temperature Analyses for Western River Lamprey Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-515

Table O-127. Summary of Results for Water Temperature Analyses for Western River Ammocoete Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-516

Table O-128. Predicted Average Monthly Loss of Western River Lamprey at Banks by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss ... O-519

Table O-129. Predicted Average Monthly Loss of Western River Lamprey at Jones by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss ... O-519

Table O-130. Summary of Results for Water Temperature Analyses for Striped Bass Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-521

Table O-131. Summary of Results for Water Temperature Analyses for Striped Bass Larvae, Fry, and Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-523

Table O-132. Summary of Results for Water Temperature Analyses for Adult Striped Bass for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-524

Table O-133. Summary of Results for Water Temperature Analyses for Juvenile Striped Bass Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-526

Table O-134. Summary of Results for Water Temperature Analyses for Striped Bass Spawning, Embryo Incubation and Initial Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-527

Table O-135. Summary of Results for Water Temperature Analyses for Larval and Juvenile Striped Bass Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-529

Table O-136. Predicted Average Monthly Loss of Striped Bass at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss..... O-532

Table O-137. Predicted Average Monthly Loss of Striped Bass at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss..... O-532

Table O-138. Summary of Results for Water Temperature Analyses for American Shad for Spawning and Larval Rearing in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-534

Table O-139. Summary of Results for Water Temperature Analyses for American Shad for Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-536

Table O-140. Summary of Results for Water Temperature Analyses for American Shad Spawning and Larval Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-537

Table O-141. Summary of Results for Water Temperature Analyses for American Shad Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-539

Table O-142. Summary of Results for Water Temperature Analyses for American Shad Spawning and Larval Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-541

Table O-143. Summary of Results for Water Temperature Analyses for American Shad Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-542

Table O-144. Predicted Average Monthly Loss of American Shad at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-546

Table O-145. Predicted Average Monthly Loss of American Shad at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-546

Table O-146. Summary of Results for Water Temperature Analyses for Threadfin Shad for Spawning in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-548

Table O-147. Summary of Results for Water Temperature Analyses for Threadfin Shad Adult Spawning for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-549

Table O-148. Summary of Results for Water Temperature Analyses for Threadfin Shad Adult Spawning for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-551

Table O-149. Predicted Average Monthly Loss of Threadfin Shad at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-553

Table O-150. Predicted Average Monthly Loss of Threadfin Shad at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-553

Table O-151. Summary of Results for Water Temperature Analyses for Black Basses Spawning in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-556

Table O-152. Summary of Results for Water Temperature Analyses for Black Bass Non-spawning Adults in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-558

Table O-153. Summary of Results for Water Temperature Analyses for Black Basses Spawning in the lower American River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results O-560

Table O-154. Summary of Results for Water Temperature Analyses for Non-spawning Black Basses in the Lower American River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results ... O-563

Table O-155. Summary of Results for Water Temperature Analyses for Black Basses Spawning in the Stanislaus River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-565

Table O-156. Summary of Results for Water Temperature Analyses for Non-spawning Black Basses in the Stanislaus River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results..... O-567

Table O-157. Predicted Average Monthly Loss of Largemouth Bass at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-570

Table O-158. Predicted Average Monthly Loss of Largemouth Bass at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-570

Table O-159. Predicted average monthly loss Smallmouth Bass at Banks by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss O-571

Table O-160. Predicted Average Monthly Loss of Smallmouth Bass at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss O-572

Table O-161. Predicted Average Monthly Loss of Spotted Bass at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss..... O-573

Table O-162. Predicted Average Monthly Loss of Spotted Bass at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss..... O-573

Table O-163. Predicted Average Monthly Loss of Starry Flounder at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss..... O-576

Table O-164. Predicted Average Monthly Loss of Starry Flounder at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss..... O-576

Table O-165. Difference in Shasta Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June[1] .. O-609

Table O-166. Percent Difference in Shasta Reservoir Storage Volume between Each Alternative and the No Action Alternative, April through October [1]..... O-610

Table O-167. Difference in Whiskeytown Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June[1] O-611

Table O-168. Percent Difference in Whiskeytown Reservoir Storage Volume between Each Alternative and the No Action Alternative, April through October[1] O-612

Table O-169. Difference in Folsom Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June[1] .. O-614

Table O-170. Percent Difference in Folsom Reservoir Storage Volume between Each Alternative and the No Action Alternative, April through October[1] O-615

Table O-171. Difference in New Melones Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June[1] O-616

Table O-172. Percent Difference in New Melones Reservoir Storage Volume between Each Alternative and the No Action Alternative, April through October[1] O-617

Table O-173. Difference in San Luis Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June [1] . O-620

Table O-174. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-624

Table O-175. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-625

Table O-176. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-626

Table O-177. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-627

Table O-178. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir storage for the No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-628

Table O-179. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir storage for the No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-629

Table O-180. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir storage for the No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-630

Table O-181. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir Storage for the No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-631

Table O-182. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-634

Table O-183. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-635

Table O-184. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-636

Table O-185. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-637

Table O-186. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-638

Table O-187. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-639

Table O-188. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-640

Table O-189. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-641

Table O-190. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-642

Table O-191. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-643

Table O-192. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-644

Table O-193. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-645

Table O-194. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-646

Table O-195. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-647

Table O-196. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-648

Table O-197. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-649

Table O-198. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-652

Table O-199. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-653

Table O-200. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-654

Table O-201. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-655

Table O-202. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-656

Table O-203. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-657

Table O-204. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-658

Table O-205. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-659

Table O-206. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-660

Table O-207. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-661

Table O-208. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-662

Table O-209. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-663

Table O-210. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-664

Table O-211. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-665

Table O-212. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-666

Table O-213. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-667

Table O-214. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River Flow at Rio Vista for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-668

Table O-215. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River Flow at Rio Vista for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-669

Table O-216. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River Flow at Rio Vista for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-670

Table O-217. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River Flow at Rio Vista for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-671

Table O-218. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-673

Table O-219. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-674

Table O-220. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-675

Table O-221. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-676

Table O-222. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-678

Table O-223. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-679

Table O-224. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-680

Table O-225. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-681

Table O-226. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Lower American River below Nimbus Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-682

Table O-227. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Lower American River below Nimbus Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-683

Table O-228. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for lower American River below Nimbus Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-684

Table O-229. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for lower American River below Nimbus Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-685

Table O-230. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-686

Table O-231. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-687

Table O-232. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-688

Table O-233. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-689

Table O-234. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-691

Table O-235. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-692

Table O-236. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-693

Table O-237. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-694

Table O-238. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-695

Table O-239. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-696

Table O-240. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-697

Table O-241. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-698

Table O-242. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them O-700

Table O-243. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them O-701

Table O-244. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them O-702

Table O-245. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them O-703

Table O-246. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 3 and Differences between Them..... O-1077

Table O-247. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir Storage for the No Action Alternative, Alternative 3 and Differences between Them O-1078

Table O-248. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 3 and Differences between Them O-1081

Table O-249. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 3 and Differences between Them O-1082

Table O-250. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 3 and Differences between Them O-1083

Table O-251. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 3 and Differences between Them O-1084

Table O-252. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 3 and Differences between Them O-1087

Table O-253. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 3 and Differences between Them O-1088

Table O-254. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 3 and Differences between Them O-1089

Table O-255. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 3 and Differences between Them O-1090

Table O-256. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River at Rio Vista flow for No Action Alternative, Alternative 3 and Differences between Them O-1091

Table O-257. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 3 and Differences between Them O-1093

Table O-258. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 3 and Differences between Them O-1095

Table O-259. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Lower American River below Nimbus Dam for No Action Alternative, Alternative 3 and Differences between Them O-1096

Table O-260. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Lower American River at H Street for No Action Alternative, Alternative 3 and Differences between Them O-1097

Table O-261. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 3 and Differences between Them O-1099

Table O-262. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 3 and Differences between Them O-1100

Table O-263. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 3 and Differences between Them O-1102

Table O-264. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for No Action Alternative, Alternative 4 and Differences between Them O-1343

Table O-265. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir storage for No Action Alternative, Alternative 4 and Differences between Them O-1344

Table O-266. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 4 and Differences between Them O-1347

Table O-267. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 4 and Differences between Them O-1348

Table O-268. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 4 and Differences between Them O-1349

Table O-269. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 4 and Differences between Them O-1350

Table O-270. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 4 and Differences between Them O-1353

Table O-271. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 4 and Differences between Them O-1354

Table O-272. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 4 and Differences between Them O-1355

Table O-273. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 4 and Differences between Them O-1356

Table O-274. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River at Rio Vista Flow for No Action Alternative, Alternative 4 and Differences between Them O-1357

Table O-275. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 4 and Differences between Them O-1359

Table O-276. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 4 and Differences between Them O-1362

Table O-277. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for lower American River below Nimbus Dam for No Action Alternative, Alternative 4 and Differences between Them O-1363

Table O-278. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 4 and Differences between Them O-1364

Table O-279. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 4 and Differences between Them O-1366

Table O-280. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 4 and Differences between Them O-1367

Table O-281. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 4 and Differences between Them O-1369

Table O-282. Summary of Aquatic Resources Impacts O-1595

Table O-283. Summary of Alternative 1 Avoidance and Minimization Measures O-1657

Table O-284. Summary of Alternative 2 Avoidance and Minimization Measures O-1658

Figures

Figure O-1. Spring-run Chinook Salmon Clear Creek Returns, 1998–2022 ..... O-62

Figure O-2. Late Fall-run Chinook Salmon Escapement, 2003–2022..... O-63

Figure O-3. Fall-run Chinook Salmon Returns, 1998–2022..... O-64

Figure O-4. Sacramento River Fall Chinook Salmon Escapement for the Upper Sacramento, Feather, and American River Basins O-80

Figure O-5. Steelhead Nimbus Hatchery Returns and In-River Spawner Estimates, American River, 2002–2022 ..... O-81

Figure O-6. Depicts Minimum Stanislaus River In-Stream Flow Schedule for Central Valley Steelhead as Measured at Goodwin Dam O-90

Figure O-7. White Sturgeon Year Class Index Through Time, 1980–2020 ..... O-118

Figure O-8. Fall Midwater Trawl Annual Abundance Indices for Delta Smelt, 1967–2022 .. O-120

Figure O-9. Fall Midwater Trawl Annual Abundance Indices for Longfin Smelt, 1967–2022..... O-126

Figure O-10. Modeled Average Monthly Water Temperatures in the Trinity River below Lewiston Dam under the No Action Alternative and Action Alternatives..... O-250

Figure O-11. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam under the No Action Alternative and the Action Alternatives in Wet Water Years O-252

Figure O-12. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam under the No Action Alternative and the Action Alternatives in Dry and Critically Dry Water Years O-253

Figure O-13. Conceptual Model for Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta..... O-293

Figure O-14. Conceptual Model of Delta Regions and Winter-run Chinook Salmon Routing Symbolized by Fish Fate..... O-300

Figure O-15. San Joaquin River at Vernalis HEC-5Q Simulated Water Temperatures under the No Action Alternative and Alternatives 1-4, October through September O-363

Figure O-16. Modeled Average March Water Temperatures in the Trinity River below Lewiston in March of Below Normal Water Years Under Each Alternative .. O-581

Figure O-17. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam in Wet Water Years O-1027

Figure O-18. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam in Above Normal Water Years O-1028

Figure O-19. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam in Below Normal Water Years O-1029

Figure O-20. Modeled November Average Water Temperature in the Trinity River below Lewiston Dam in Above Normal Water Years O-1034

Figure O-21. Modeled December Average Water Temperature in the Trinity River below Lewiston Dam in Below Normal Water Years O-1034

Appendix O Fish and Aquatic Resources Technical Appendix

This appendix describes the fish and aquatic resources that occur in the portions of the study area that could be affected as a result of implementing the alternatives evaluated in this environmental impact statement (EIS). Implementation of the alternatives could affect aquatic resources through changes in ecological attributes as a result of potential changes in long-term operation of the Central Valley Project (CVP) and State Water Project (SWP).

Potential actions implemented under the alternatives evaluated in this EIS could affect fish and aquatic resources. Actions located on public agency lands, or implemented, funded, or approved by federal and state agencies, would need to be compliant with appropriate federal and state agency policies and regulations.

CEQ guidance for NEPA do not require significance determinations in an EIS but do require a discussion of the context and intensity of the impacts as defined in 40 CFR (§650.4) (k) (1).

O.1 Affected Environment

This section describes fish and aquatic resources that could be affected by the implementation of the action alternatives considered in this EIS.

The following description of the affected environment focuses on CVP and SWP reservoirs, rivers downstream of CVP and SWP reservoirs, the Sacramento–San Joaquin Bay-Delta (Delta), and conditions downstream of the Delta that are affected by operation of the CVP and SWP.

The descriptions of species and biological and hydrodynamic processes in this appendix frequently use the terms *Delta* and *San Francisco Estuary*. The *Delta* refers to the Sacramento–San Joaquin Delta, as legally defined in the Delta Protection Act. The *San Francisco Estuary* refers to the portion of the Sacramento–San Joaquin Rivers watershed downstream of Chipps Island that is influenced by tidal action and where freshwater and saltwater mix, which includes the following water bodies: Suisun, San Pablo, and San Francisco Bays.

O.1.1 Fish and Aquatic Species Evaluated

Many fish and aquatic species use the study area during all or some portion of their lives; however, certain fish and aquatic species were selected to be the focus of this analysis based on their sensitivity and their potential to be affected by changes in the operation of the CVP and SWP implemented under the alternatives considered in this EIS, as summarized in Table O-1. While many of the species identified in Table O-1 also occur in tributaries to the major rivers, the focus of this EIS is on the water bodies influenced by operations of the CVP and SWP. Operation of the CVP and SWP would not directly affect ocean conditions; however, operations have the potential to affect Southern Resident killer whales (Southern Residents) indirectly by influencing the number of Chinook salmon (produced in the Trinity River and the Sacramento and San Joaquin Rivers and associated tributaries) that enter the Pacific Ocean and become available as a food supply for the whales.

These focal species are fish and marine mammal species listed as threatened or endangered or at risk of being listed threatened or endangered, legally protected, or are otherwise considered sensitive by the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS), and that have tribal, commercial, or recreational importance. In addition, salmon, steelhead, sturgeon, striped bass, and American shad are managed in accordance with Section 3406 of the Central Valley Project Improvement Act (CVPIA). Details on the status, life history, habitat requirements, and population trends for each of the federally listed aquatic focal species are provided in the *Biological Assessment for the Long-Term Operations of the Central Valley Project and State Water Project*.

Table O-1. Focal Aquatic Species by Region of Occurrence

Species or *Population*	**Federal Status**	**Tribal [1], Commercial [2], or Recreational Importance**	**Occurrence within Area of Analysis**
Coho Salmon *Southern Oregon/Northern California Coast ESU*	Threatened	Yes	Trinity River
Chinook Salmon *Upper Klamath-Trinity River Spring-Run ESU*	Candidate	Yes	Trinity River
Chinook Salmon *Upper Klamath-Trinity River Fall-Run ESU*	Candidate	Yes	Trinity River

[1] Tribal importance was noted based on Shilling et al. (2014).
[2] Commercially important species with Essential Fish Habitat under the Magnuson-Stevens Fishery Conservation and Management Act.

Species or *Population*	Federal Status	Tribal [1], Commercial [2], or Recreational Importance	Occurrence within Area of Analysis
Steelhead *Klamath Mountains Province DPS*	None	Yes	Trinity River
Eulachon *Southern DPS*	Threatened	Yes	Lower Klamath River
Green Sturgeon *Northern DPS*	None	Yes	Trinity River, Lower Klamath River
Coastal Cutthroat Trout	None	Yes	Lower Klamath River
Brown Trout	None	Yes	Trinity River, Lower Klamath River, Trinity Lake
Rainbow Trout	None	Yes	Trinity Lake
Kokanee Salmon (landlocked Sockeye Salmon)	None	Yes	Trinity Lake
Chinook Salmon *Sacramento River* Winter-Run ESU	Endangered	Yes	Sacramento River, Bay-Delta
Chinook Salmon *Central Valley Spring-Run ESU*	Threatened	Yes	Clear Creek, Sacramento River, Bay-Delta
Steelhead *California Central Valley DPS*	Threatened	Yes	Clear Creek, Sacramento River, American River, Stanislaus River, San Joaquin River, Bay-Delta
Green Sturgeon *Southern DPS*	Threatened	Yes	Sacramento River, Bay-Delta
Delta Smelt	Threatened	Yes	Bay-Delta
Longfin Smelt *San Francisco Bay-Delta DPS*	Endangered	Yes	Bay-Delta
Chinook Salmon *Central Valley Fall-Run/Late Fall-run ESU*	None	Yes	Clear Creek, Sacramento River, American River, Stanislaus River, Bay-Delta, San Joaquin River
White Sturgeon	Petitioned	Yes	Sacramento River, American River, Bay-Delta, San Joaquin River
Native Minnows (Sacramento Splittail, Hardhead, Sacramento Hitch)	None	Yes	Clear Creek, Sacramento River, American River, Bay-Delta, Stanislaus River, San Joaquin River
Pacific Lamprey	None	Yes	Trinity River, Clear Creek, Sacramento River, American River, Bay-Delta, Stanislaus River, San Joaquin River

Species or *Population*	Federal Status	Tribal [1], Commercial [2], or Recreational Importance	Occurrence within Area of Analysis
Western River Lamprey	None	Yes	Sacramento River, American River, Stanislaus River, Bay-Delta, San Joaquin River
Striped Bass	None	Yes	Sacramento River, American River, Bay-Delta, Stanislaus River, San Joaquin River
American Shad and Threadfin Shad	None	Yes	American River, Sacramento River, Bay-Delta, Stanislaus River, San Joaquin River
Black Basses (Largemouth, Smallmouth, Spotted)	None	Yes	Trinity Lake, Sacramento River, American River, Bay-Delta, Stanislaus River, San Joaquin River
Starry Flounder	None	Yes	Bay-Delta
Killer Whale, *Southern Resident DPS*	Endangered	Yes	Nearshore Pacific Ocean

ESU = evolutionary significant unit; DPS = distinct population segment; SSC = species of special concern.

The life history attributes (e.g., timing of juvenile outmigration) for most of the species listed above, along with the ecological attributes important to the species and potentially influenced by the alternatives, are discussed in this appendix according to the geographic areas (regions/subregions) where the species occurs. Pacific lamprey, green sturgeon, white sturgeon, American shad, and striped bass are discussed in detail only in those regions where they spend the majority of their life cycle such that geographic information is available.

The level of detail presented here is tailored to correspond the level of resolution of the analysis, which relies on modeling tools that broadly characterize the changes in CVP and SWP operations on reservoir storage and flows. This level of detail is intended to support an understanding of the resources potentially affected and the context within which the project is evaluated.

O.1.2 Trinity River

The Trinity River is a designated National Wild and Scenic River in northern California, flowing 165 miles from the Trinity Alps and joining with the Klamath River before flowing into the Pacific Ocean. The Trinity River flows through Trinity and Humboldt Counties and through the Hoopa Indian Reservation. The lower Klamath River flows through Humboldt and Del Norte Counties and through the Hoopa, Yurok, and Resighini Indian reservations. The Trinity River is deeply ingrained in the lives of the Hoopa Valley and Yurok tribes, providing a valuable natural resource that has supported each tribe nutritionally, spiritually, and commercially for thousands of years.

The Trinity River was shaped by natural variations in flow due to changing seasons and annual flooding. In the winter and spring, snowmelt contributed to high flows that washed fine sediment downstream, leaving large pools and spawning gravel for fish habitat. The cycle of low flows in the dry summer and high flows in the winter and spring allowed insects to flourish and feed juvenile and adult fish. The natural shift in flows created a diverse and productive river channel.

However, historical gold mining and logging substantially altered the Trinity River's hydrology and geomorphology, degraded riparian conditions, reduced channel complexity, disconnected floodplains, increased sediment deposition from severe hillside erosion, and buried fertile soil and wildlife habitat under tailing piles. Dam construction blocked fish passage and impaired sediment transport while the CVP operations diverted up to 90% of water from the river to the Central Valley, altering flow variability and further reducing coarse sediment input to downstream locations. Combined, these impacts substantially reduced the quantity and quality of aquatic habitat.

These alterations hindered important fluvial processes that support riparian habitat and river channel dynamics. The reduction in high flow events, which historically would have led to river channel meander and scouring of riparian vegetation within the active floodplain, allowed for vegetation to encroach on areas along the active river channel, creating a more stable berm along the channel and reducing the potential for lateral channel movement and overbank flows. The resulting narrow channel and high berm acts as a natural levee that isolates the channel from the floodplain, preventing recruitment of young trees and shrubs and increasing flow velocities that carved the channel deeper over time, reducing aquatic habitat complexity and suitability for native fish species.

O.1.2.1 Water Operations Management

Flow

The Trinity River region includes Trinity Reservoir and Lewiston Reservoir, the Trinity River down to the Klamath River, and the lower Klamath River from the confluence with the Trinity River. The Trinity River flows through Trinity and Humboldt counties and through the Hoopa Indian Reservation. The lower Klamath River flows through Humboldt and Del Norte counties and through the Hoopa, Yurok, and Resighini Indian reservations. Lewiston Reservoir is directly downstream of Trinity Reservoir; the two reservoirs were built in the 1960s as part of the CVP to divert water from the Trinity River to the Sacramento River. Flows in the Trinity River are regulated by water releases from these two reservoirs. Downstream of Lewiston Reservoir, the Trinity River flows for 112 miles, receiving water from several tributaries, including the North Fork Trinity River, the South Fork Trinity River, and New River, before entering the Klamath River. Flows in these tributaries are not affected by CVP operations.

Water Temperature

Water temperature targets on the Trinity River are specified at Douglas City (RM 93.8) and above the confluence of the North Fork Trinity River (RM 72.4) to aid salmon upstream migration, holding, and juvenile growth. Douglas City water temperature targets are 60°F from July 1st through September 14th, and 56°F from September 15th through September 30th. North Fork Trinity River temperature target is 56°F from September 15th through September 30th. Recommended water temperatures targets by TRRP for juvenile salmonids at North Fork Trinity River and Lewiston (RM 110.2) are 55.4-61.7°F (April 1st through July 31st), less than 53.4°F (September 15th through October 31st), and less than 50°F (November 1st through February 28th) (Buxton 2023).Trinity River Restoration Program

The Trinity Management Council, a multi-agency partnership, established the Trinity River Restoration Program (TRRP) and works with its many collaborators to *"mitigate impacts of the Trinity River Division of the CVP on anadromous fish populations in the Trinity River by successfully implementing the 2000 Trinity River Record of Decision and achieving Congressionally mandated restoration goals."* The 2000 Record of Decision directs the U.S. Department of the Interior to restore the fisheries of the Trinity River impacted by dam construction and related diversions of the Trinity River Division that compounded the historical gold mining and logging impacts.

The long-term goals of the TRRP are:

1. to restore the form and function of the Trinity River;
2. to restore and sustain natural production of anadromous fish populations to pre-dam levels; and
3. to facilitate full participation by dependent tribal, commercial, and sport fisheries through enhanced harvest opportunities.

Since the 2000 Record of Decision, many fish habitat rehabilitation projects have been completed and are ongoing in the 40-mile section of the Trinity River from Lewiston Dam to the confluence with the North Fork Trinity River (Trinity River Restoration Program 2023b), with more planned for the future. Restoration projects to date have increased fish habitat complexity for various life stages of anadromous salmonids, reestablished floodplain connectivity by removing riparian berms that confine the river and fluvial processes, decreased the input of fine sediment from Trinity River tributaries that can reduce spawning gravel quality and fill pools, augmented coarse sediment to enhance spawning and rearing habitat, and addressed necessary infrastructure modifications to accommodate a more dynamic river system (i.e., bridge, well, and septic system modifications or relocations).

In 2000, the U.S. Department of the Interior reduced the amount of water being diverted to the Central Valley and gave TRRP a mandate to recommend flow releases that would benefit the ecology of the river. TRRP instream flow releases since 2000 have included static summer (450 cubic feet per second [cfs]) and winter (300 cfs) baseflows supplemented with variable annual instream flow releases based on water year type, with restoration flow releases being implemented following the water year determination in mid-April. This approach led to an asynchrony between managed flow releases and natural flow variability, with managed flow releases and cooler water temperatures extending later in the spring.

Specific to Water Year 2023 and through adaptive management, the TRRP tested how restoration flow releases are managed with implementation of the Winter Flow Project, which manages flows across a broader portion of the year to more closely mimic natural flow and water temperature characteristics (Abel et al. 2022; Trinity River Restoration Program 2023a). The Winter Flow Project and winter flow variability goals and objectives allow a portion of the available annual water volume to be used during the winter period (mid-December through mid-April).

The intended benefits of shifting flow releases earlier in the year were to:

1. Better match natural flow variability and enhance natural cleaning and transport of river gravels;
2. Limit the impact that cold water from the dam has on the growth of juvenile salmon;
3. Allow the river to naturally warm earlier in the season to provide the environmental cues salmon and steelhead smolts rely upon in timing their outmigration to the ocean;
4. Provide elevated flows before salmon fry emergence to increase food availability and increase access to floodplain nursery habitats; and
5. Maintain more consistent reservoir levels in Trinity Reservoir through the summer months.

As evaluated, winter flow releases could be managed within two distinct periods: the Flow Synchronization Period (December 15 through February 15), and the Elevated Baseflow Period (February 15 through April 15). After April 15, restoration flow releases could follow the same methods used in previous years. The maximum winter release for winter flow variability actions would differ from year to year based on water year type, as follows:

- 60,000 acre-feet in a Critically Dry water year,
- 80,000 acre-feet in a Dry water year,
- 120,000 acre-feet in a Normal water year,
- 180,000 acre-feet in a Wet water year, and
- 220,000 acre-feet in an Extremely Wet water year

Water year type is based on state forecast inflow to Trinity Reservoir (Stalnaker and Wittler 2000).The TRRP's Integrated Assessment Plan outlines the adaptive management plan for the TRRP, which is intended to identify key assessments that:

1. Evaluate long-term progress toward achieving Program goals and objectives; and
2. Provide short-term feedback to improve Program management actions by testing key hypotheses and reducing management uncertainties.

O.1.2.2 Trinity and Klamath River Portions of the Study Area

The Trinity and Klamath River portions of the study area comprise Trinity Reservoir and Lewiston Reservoir, the Trinity River from Lewiston Dam to the Klamath River, and the lower Klamath River from the confluence with the Trinity River to the Pacific Ocean. Lewiston Reservoir is directly downstream of Trinity Reservoir; the two reservoirs were built in the 1960s as part of the CVP to divert water from the Trinity River to the Sacramento River. Flows in the Trinity River are regulated by water releases from these two reservoirs.

Downstream of Lewiston Reservoir, the Trinity River flows for 112 miles, receiving water from several tributaries, including the North Fork Trinity River, the South Fork Trinity River, and the New River, before entering the Klamath River. Flows in these tributaries are not affected by CVP operations.

The lower Klamath River flows approximately 43 miles from the confluence with the Trinity River before entering the Pacific Ocean. There are no dams on the lower Klamath River downstream of the confluence with the Trinity River. The lower five miles of the Klamath River are within the Klamath River Estuary, which is generally influenced by tidal fluctuations, with saltwater occurring up to four miles upstream of the mouth of the Klamath River, especially when high tides correspond with low flow conditions.

O.1.2.3 Trinity Reservoir

Trinity Reservoir lies upstream of Trinity Dam. It is a relatively deepwater reservoir with oligotrophic conditions based on low levels of nutrients (e.g., phosphates, nitrogen, and organic matter) and consequently low productivity (U.S. Fish and Wildlife Service et al. 2004). Trinity Lake has a storage capacity of 2.4 million acre-feet.

Fish in Trinity Reservoir

No special-status fish species occur in Trinity Reservoir.

Trinity Reservoir supports several native and nonnative fisheries that provide substantial recreational fishing opportunities. The predominant sportfish in Trinity Reservoir include both coldwater species and warmwater species. Coldwater species include rainbow trout, brown trout, Kokanee (landlocked sockeye salmon), and landlocked Chinook salmon. Warmwater species include black basses (smallmouth and largemouth bass) and catfish (white catfish and brown bullhead).

Other native fish species that occur in Trinity Reservoir but are not the focus of recreational fishing include speckled dace, Klamath smallscale sucker, and coast range sculpin. Other nonnative fish species that occur in Trinity Reservoir but are not the focus of recreational fishing include green sunfish.

Coldwater fish species in the lake generally migrate into tributaries to spawn either during the spring (rainbow trout) or fall (Kokanee and brown trout). Populations of rainbow trout, brown trout, and Kokanee are sustained through a combination of natural reproduction and fish hatchery stocking practices. Landlocked Chinook salmon do not typically reproduce (Perales et al. 2015) and are supported by annual stocking practices.

Rainbow trout fry emerge 3–4 weeks after fertilization and will remain in the gravel for about 2–3 weeks (Moyle 2002; U.S. Fish and Wildlife Service 1984 – Habitat Suitability Information: Rainbow Trout – FWS/OBS-82/10.60). Juvenile rainbow trout may spend two summers in their natal stream and two summers in a reservoir or lake before maturing. Brown trout fry typically hatch in two months, though it can range from 1–5 months depending on water temperature, and larvae will emerge from the gravel around one month later. Juveniles will spend several years in tributaries before emigrating to the reservoir where they will become sexually mature (Moyle 2002; Belica 2007).

The life expectancy of rainbow trout can be 4–8 years in northern California lake populations. After maturing, resident rainbow trout will migrate upstream to spawn in tributaries. They can spawn annually and will quickly move back downstream to the reservoir or lake (Moyle 2002), moving to cooler, deeper waters during the summer months (Belica 2007). Brown trout typically become sexually mature at age two or three and can live for up to nine years in California, spawning several times during their life (Moyle 2002; Belica 2007). Brown trout will use varying habitats within the reservoir and will also move to cooler waters in the summer habitats (Belica 2007).

Warmwater fish species (smallmouth bass, largemouth bass, white catfish, and brown bullhead) typically rely on habitat in the lake during all life stages. In general, black basses spawn during the late spring and early summer in shallow water (1.5 feet to 6.0 feet deep) along the lake margins at water temperatures ranging from 55°F to 75°F (Moyle 2002). These nests are vulnerable to fluctuations in water levels. Rapid drops in water levels may cause guarding males to abandon the nests, increase predation, and limit water circulation and dissolved oxygen levels around the eggs (U.S. Fish and Wildlife Service 1983 – Habitat Suitability Information: Smallmouth Bass – FWS/OBS-82/10.36). White catfish spawning typically occurs during June and July when water temperatures exceed 68°F, but spawning can sometimes extend into September; spawning occurs in sandy substrate adjacent to cover (e.g., rocks, wood, or aquatic vegetation) (Moyle 2002). Brown bullhead spawn from May through mid-July and will build their nests in sand or gravel near cover (Moyle 2002). Warmwater fish species in Trinity Reservoir are currently self-sustaining through natural reproduction.

Smallmouth and largemouth bass fry prefer shallow water and are vulnerable to fluctuations in water levels. These fry hatch in 2–7 days and then spend another week in the nest. Larval bass stay in shallow water on the edge of vegetation (Moyle 2002). Rapid drops in water levels may cause stranding. Juvenile bass tend to live in deeper water habitats with submerged shelter (e.g., logs or boulders). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002).

Warmwater species will remain in the reservoir their entire lives. Smallmouth bass prefer narrow bays and upstream ends of reservoirs or along the shore where rocky shelves are present at a depth of 3–30 ft (Moyle 2002). They become sexually mature at age 3–4 and typically live less than 7 years (U.S. Fish and Wildlife Service 1983 – Habitat Suitability Information: Smallmouth Bass – FWS/OBS-82/10.36). Age of largemouth bass in California reservoirs is 4–5 years and they typically spawn during their second season (Moyle 2002). Adult bass tend to prefer deeper,

colder waters in lakes and reservoirs in areas with vegetation and other forms of cover (U.S. Fish and Wildlife Service 1983 – Habitat Suitability Information: Largemouth Bass – FWS/OBS-82/10.16). They become sexually mature at age three and will spawn multiple times during their lifetime of up to 8–10 years (Moyle 2002).

O.1.2.4 Lewiston Reservoir

Directly downstream of Trinity Reservoir is Lewiston Reservoir which is a re-regulating reservoir for Trinity Reservoir and has a storage capacity of 14,660 acre-feet. Lewiston Reservoir receives cold water released from the bottom of Trinity Reservoir, and the water surface elevation remains relatively constant throughout the year.

Fish in Lewiston Reservoir

Lewiston Reservoir supports native and nonnative recreational fisheries. The predominant sportfish in Lewiston Reservoir include both coldwater species and warmwater species. Coldwater species include rainbow, brown, and brook trout along with Kokanee salmon. Warm water species include nonnative smallmouth and largemouth bass.

Other native fish species found in Lewiston Reservoir that are not the focus of recreational fishing are native speckled dace, Klamath smallscale sucker, and coast range sculpin. There may also be a landlocked population of Pacific lamprey (Moyle et al. 2015).

Spawning timing for fish species in Lewiston Reservoir is the same as described for Trinity Reservoir.

O.1.2.5 Trinity River from Lewiston Dam to the Confluence with Klamath River

Flows in the Trinity River downstream of Lewiston Dam are heavily influenced by releases from Lewiston Reservoir and Trinity Reservoir. This section of the mainstem Trinity River and its tributaries support several anadromous fish species considered in this EIS.

Fish in the Trinity River from Lewiston Dam to the Confluence with Klamath River

The analysis is focused on the following species:

- Coho salmon, Southern Oregon/Northern California Coast Distinct Population Segment (DPS)
- Spring-run Chinook salmon, Upper Klamath-Trinity River evolutionarily significant unit (ESU)
- Fall-run Chinook salmon, Upper Klamath-Trinity River ESU
- Steelhead, Summer-run, fall-run, and winter-run; Klamath Mountains Province DPS
- Green sturgeon, Northern DPS
- Pacific lamprey
- Brown trout

Coho salmon, Southern Oregon/Northern California Coast ESU

The Southern Oregon/Northern California Coast coho salmon ESU was listed as threatened under the ESA in 1997 because of the reduced range, decreased abundance, and degraded habitat of coho salmon populations (62 FR 24588). On June 28, 2005, NMFS reaffirmed the threatened status of the ESU (70 FR 37160). The ESU consists of naturally spawned coho salmon populations originating between Punta Gorda, California and Cape Blanco, Oregon (National Marine Fisheries Service 2014).

Coho salmon in the Trinity River system generally exhibit a three-year life cycle during which they spend the first year in freshwater before migrating out to the ocean, where they spend the next two years maturing, and then return to their natal stream to spawn and die. Adult coho salmon typically enter the Trinity River between September and January, and timing of coho salmon river entry is influenced by several factors, including genetics, stage of maturity, river discharge, and access past the river mouth.

Coho salmon spawning occurs mostly in November and December. Spawning occurs in the mainstem Trinity River and its tributaries, with peak coho salmon spawning activities in the mainstem Trinity River occurring between Lewiston Dam and the North Fork Trinity River. Spawning is concentrated in riffles or in gravel deposits at the downstream end of pools with suitable water depth, velocity, and substrate size. Most coho salmon spawning in the mainstem Trinity River occurs in November and December between Lewiston Dam and the North Fork Trinity River (Section O.1.2.5.1, *Coho salmon, Southern Oregon/Northern California Coast ESU*). Based on recent weir counts, the date of peak abundance of upstream-migrating coho salmon in the Trinity River ranges from late September to mid-November (Kier et al. 2018, 2019, 2020, 2021, 2022). After completing their upstream migration, mature coho salmon may hold for days, weeks, or sometimes months before spawning.

Coho salmon eggs and alevins in the Trinity and Klamath basins may be present in the gravel from November to mid-May (Leidy and Leidy 1984). Naturally spawned juvenile coho salmon in the Trinity River emerge from the gravel and begin rearing in winter and early spring, with the first captures of young-of-year (age-0) coho salmon typically occurring in early March (U.S. Fish and Wildlife Service 2023, unpublished; Yurok Tribe 2023, unpublished). Rearing occurs year-round, typically over a period of 12–15 months. Fry, juvenile, and subyearling coho salmon rearing in the Trinity River strongly prefer areas of slow water velocity and habitat with small and large woody material, overhanging vegetation, and clusters of aquatic vegetation (Hampton 1988, 1997; Chase et al. 2009; Pinnix et al. 2019). During high flows, young coho salmon use floodplains and other off-channel habitats (Chase et al. 2009). Most Trinity River coho salmon outmigrate to the ocean as yearling smolts between January and June or July (Harris et al. 2016; Petros et al. 2015; Petros et al. 2017). From August to January, coho salmon return from the ocean through the Klamath River Estuary to the Trinity River, moving upstream toward spawning habitat.

Coho salmon were not likely the dominant species of salmon in the Trinity River before dam construction. They were, however, found throughout the Trinity Basin ranging as far upstream as Stuarts Fork above Trinity Dam. Approximately 109 miles of coho salmon habitat in the Trinity River became inaccessible after Lewiston Dam was built. To mitigate for the loss of upstream habitat, the Trinity River salmon and Steelhead Hatchery was constructed near Lewiston Dam

and produces coho salmon with an annual production goal of 500,000 yearling fish (California Hatchery Scientific Review Group 2012). Today, wild coho salmon are not abundant in the Trinity River, and most of the coho salmon that return to the river are of hatchery origin. NMFS (2014b) considers this proportion of hatchery fish in the population a high-level risk factor for the continued existence of coho salmon in the Trinity River basin. In 2014, annual coho salmon production was reduced to 300,000 yearlings pending adoption of a Trinity River Hatchery Genetics Management Plan (HGMP). The HGMP for the operation of the Trinity River Hatchery was approved by NMFS in 2019 and efforts began in 2021 to focus on natural environmental selection for the Trinity coho salmon population and incorporating more natural origin fish into the breeding population at the Trinity River Hatchery (Hoopa Valley Tribe et al. 2022).

Coho salmon run-size estimates have ranged from 852 fish in 1994 to 59,079 fish in 1987. In 2021, an estimated 4,694 adult coho salmon migrated into the Trinity River basin upstream of Willow Creek about 88 miles downstream of Lewiston Dam. Of these, 2,346 entered the Trinity River Salmon and Steelhead Hatchery, while the remaining 2,348 fish were believed to have spawned in the river (Kier et al. 2022). Available spawning habitat for coho salmon downstream of Lewiston Dam is thought to be near carrying capacity (National Marine Fisheries Service 2014b).

Several interrelated factors affect coho salmon abundance and distribution in the Trinity River including water temperature, water flow, habitat suitability, habitat availability, hatcheries, predation, competition, disease, ocean conditions, and harvest (National Marine Fisheries Service 2014b). Current CVP operations primarily affect water temperature, water flow, and habitat suitability in the Trinity River. Climate change also affects water temperature, water flow, and habitat suitability in the Trinity River.

Habitat for coho salmon in the Trinity River has changed since flow regulation; the encroachment of riparian vegetation has restricted channel movement and limited fry rearing habitat (Trush et al. 2000). According to the TRRP, higher peak flows are needed to restore attributes of a more alluvial river, such as alternate bar features and more off-channel habitats. These flows are projected in the TRRP to provide better rearing habitat for coho salmon than the dense riparian vegetation currently present. Physical habitat manipulations described above have improved juvenile rearing in selected sites along the river.

Spring-run Chinook Salmon, Upper Klamath-Trinity River ESU

Adult spring-run Chinook salmon typically enter the Trinity River from April through September. By the end of July, most fish have arrived at the primary spawning reach, which extends from Lewiston Dam downstream to the mouth of the North Fork Trinity River. After entering freshwater, spring-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically ranges from the third week of September through November, peaking in October. Most spring-run Chinook salmon in the Trinity River spawn from late September to mid-November, with a peak in October (Gough et al. 2021a, 2021b). At optimal intragravel temperatures (41–55°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another 4–6 weeks (Healey 1991; Moyle 2002).

In the Trinity River, spring-run Chinook salmon incubation and emergence typically occurs through February (Leidy and Leidy 1984). Peak out-migration occurs in May, June, and July based on monitoring in the lower Trinity River near the town of Willow Creek (Harris et al. 2016; Petros et al. 2017). Natural juvenile spring-run Chinook salmon typically out-migrate as sub-yearlings from the Trinity River with a few yearling juveniles outmigrating. Hatchery releases of spring-run Chinook salmon also include mostly sub-yearlings and some yearling releases in spring and fall, respectively. Fry and juvenile Chinook salmon rearing in the Trinity River preferentially use areas of relatively slow water velocity and habitat with woody material, undercut banks, and other complex cover (Hampton 1988; Pinnix et al. 2019).

Historically, spring-run Chinook salmon were likely the most abundant salmonid species in the Trinity River (Snyder 1931; LaFaunce 1967). Spring-run Chinook salmon historically spawned in the Trinity River and several of its tributaries upstream of Lewiston Dam (e.g., East Fork Trinity River, Stuart Fork, Coffee Creek, Hayfork Creek [Gibbs 1956; Campbell and Moyle 1991]). The completion of dams on the Trinity River in the 1960s blocked access to 59 miles of habitat, most of which was considered prime spawning and nursery habitat (Moffett and Smith 1950).

The current spring-run Chinook salmon population for the Klamath and Trinity River basins is estimated to be 10% of historical levels (Myers et al. 1998). The estimated average run size for spring-run Chinook salmon in the Trinity River from 1991 through 2021 is 13,526, with 61.1% of the run composed of hatchery-origin fish (Kier et al. 2022). In 2021, the estimated total run size was 5,550 with 81.5% of fish being of hatchery origin (Kier et al. 2022). This was 36.4% of the 43-year average of 15,495 since 1978. Williams et al. (2011) concluded that although abundance was low compared with historical abundance, the spring-run Chinook salmon population (which includes hatchery fish) appears to have been variable but stable from 1980 to 2021. It should be noted, however, that there has been a marked decline in run size estimates in recent years. Except for a 2019 run-size estimate of 12,612 fish, spring-run Chinook salmon estimates for the Trinity River have been less than 10,000 fish since 2012, with more than half of the fish being of hatchery origin (Kier et al. 2020). From 1991–2012, the estimated average run size for spring-run Chinook salmon in the Trinity River was 16,553 (including hatchery fish) and from 2013–2020 the average run size estimate was 6,462 fish (including hatchery fish) (Kier et al. 2022).

Fall-run Chinook Salmon, Upper Klamath

<u>Trinity River ESU</u>

Adult fall-run Chinook salmon typically enter the Trinity River from September through October (Moyle et al. 2015). Two to four weeks after river entry, adults have made it to the primary spawning reach which extends from Lewiston Dam downstream to the mouth of the North Fork Trinity River and the Hoopa Valley (Myers et al. 1998). After entering freshwater, fall-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically ranges from the third week of September through November, peaking in October (Chesney and Knechtle 2012). Optimal spawning temperatures for spawning are reported to be less than 55.4°F (Moyle 2002). Spawning activity typically begins just downstream of Lewiston Dam and then extends farther downstream as the spawning season progresses.

In the Trinity River, fall-run Chinook salmon incubation and emergence typically occurs from December through late February (Leidy and Leidy 1984). At optimal intragravel temperatures (43–54°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another 4–6 weeks (Moyle 2002). Similar to spring-run Chinook salmon, emergence of fall-run Chinook salmon fry begins in December and continues into mid-April.

Juvenile fall-run Chinook salmon typically spend a few months rearing in the Trinity River before they out-migrate. Natural juvenile fall-run Chinook salmon primarily outmigrate as sub-yearlings from the Trinity River and less occasionally as yearlings. Hatchery releases of fall-run Chinook salmon also include mostly smolts and some yearling releases in late spring and fall, respectively. Though the timing of juvenile out-migration is highly variable, near Lewiston Dam, out-migration typically occurs from March through May, with peak out-migration occurring in early May, while out-migration in the river farther downstream typically peaks in May and June (Moyle et al. 2015) but can extend to July based on monitoring in the lower Trinity River near the town of Willow Creek (Moyle 2002; Chesney and Yokel 2004). However, there is some uncertainty in the outmigration timing because spring-run and fall-run Chinook salmon juvenile outmigration timing overlaps and they cannot always be differentiated in the field.

The estimated average run size for fall-run Chinook salmon in the Trinity River from 1977 through 2021 is 39,453, making it the most abundant salmonid species currently in the Trinity River (Kier et al. 2022). Fall-run Chinook salmon are nearly equally represented by wild and hatchery fish, with an average of 50.3% of the fish estimated to be of hatchery origin for the period of 1991 to 2021 (Kier et al. 2022). Overall, the population of fall-run Chinook salmon in the Trinity River is highly variable, with estimated returns between 1991 and 2021 ranging from a high of 105,725 fish (1995) to a low of 6,196 fish (2017). The 2021 estimated total run size of 22,623 was 57.3% of the 45-year average since 1977 (Kier et al. 2022).

Steelhead, Klamath Mountains Province DPS

Steelhead in the Trinity River exhibit three primary adult life history variations based on freshwater entry timing, reproductive biology, and spawning strategy (Busby et al. 1996) including: a summer-run, a fall-run, and a winter-run (Moyle et al. 2015), though steelhead life history may be even more complex in the Klamath River basin. Hodge et al. (2016) identified 38 life history categories for mature steelhead in the lower Klamath River basin (including the Trinity River) using scale and otolith strontium isotope analysis. The life histories observed differed in duration of ocean and freshwater rearing, age at maturity, and anadromy (Hodge et al. 2016) though nonanadromous life histories were included in their study.

Summer- and fall-run steelhead mature after entering freshwater (stream maturing) and winter-run steelhead mature prior to entering fresh water (ocean maturing) (Moyle et al. 2015). In addition, a “half-pounder” life history variant may be produced by any of the adult life history variations. The half-pounder life history variant includes individuals that outmigrate and spend 2-4 months in the estuary or nearshore marine environment before returning as immature subadults. Half-pounders typically overwinter in the Klamath and Trinity rivers and return to the ocean the following spring (Moyle et al. 2015). They have been observed in the Trinity River primarily October through March (Moyle et al. 2017; Moyle et al. 2015; Pinnix et al 2007).

Spawning across run types in the Trinity River may occur anytime from December through May but occurs primarily from December through February. Adult summer-run steelhead enter the Klamath Basin between April and August and arrive in the Trinity River primarily in April and May (Moyle et al. 2017; Moyle et al. 2015; Pinnix et al 2007). Summer-steelhead hold until the spawning season, in deep pools within the mainstem or upper reaches of cool tributaries while they mature (Moyle 2002; Busby et al. 1996). Summer-run steelhead tend to spawn in smaller streams higher in the drainage network than fall- or winter-run steelhead (Roelofs 1983). Consistent adult monitoring data are limited by environmental conditions and challenges in overlapping populations with different run timing, kelting or "runbacks", and half pounders but summer/fall steelhead (stream-maturing steelhead) are thought to return from the ocean about April through November and hold for varying lengths of time in the Klamath-Trinity watershed (Moyle et al. 2017; Moyle et al. 2015; Pinnix et al 2007).

Adult fall-run steelhead enter the Klamath River basin between July and November and arrive in the Trinity River primarily in July and August. Spawning for adult fall-run steelhead primarily occurs from January through May (Moyle et al. 2017; Moyle et al. 2015; Pinnix et al 2007). Meanwhile, adult winter-run steelhead enter the Klamath River basin and Trinity River from November through March and primarily spawn in the Trinity River from February through April (Moyle et al. 2017; Moyle et al. 2015; Pinnix et al 2007). Winter steelhead (ocean-maturing steelhead) can return from the ocean about November through March (Moyle et al. 2017; Moyle et al. 2015; Pinnix et al 2007). Given the overlapping run timings and varying life history strategies, adults at various stages of maturation can enter the Klamath-Trinity watershed, hold in Trinity River, and/or migrate up or down Trinity River and into tributaries in any month of the year.

Incubation across all three runs can occur anywhere from December through June, and steelhead eggs and alevins across run types in the Trinity River may be present in the gravel at any time during this period. Rearing or moving (migrating or redistributing) fry and/or juveniles can occur downstream of Lewiston Dam any time of year with three peak emigration times in March, May/June, and October/November.

Juveniles remain in freshwater for up to three years. Most steelhead (86%) that return to the Klamath River basin are estimated to spend two years in freshwater before out-migrating to the ocean (Hopelain 1998). However, summer-run steelhead may begin their out-migration at an earlier age (Scheiff et al. 2001; Pinnix and Quinn 2009; Pinnix et al. 2013). Juvenile steelhead may out-migrate from the tributaries at age 0+ or 1+ and then rear in the mainstem or in nonnatal tributaries (particularly during periods of poor water quality) for another year or two before migrating out to the ocean. Out-migration on the Trinity River lasts from spring through fall and there are three peak juvenile-out-migration periods: March, May/June, and October/November (U.S. Fish and Wildlife Service et al. 2004).

Summer-run steelhead were likely common in the snowmelt-fed upper mainstem Trinity River in the 1940s (Moffett and Smith 1950). An estimated 8,000 adult summer-run steelhead occurred on average in the Trinity River upstream of Lewiston Dam prior to its construction (California Department of Fish and Game/U.S. Fish and Wildlife Service 1956, as cited in U.S. Fish and Wildlife Service et al. 2004). Suitable habitat conditions are available downstream of Lewiston Dam and in some of the larger tributaries to the Trinity River (e.g., the north and south forks of

the Trinity River, New River, and Canyon Creek [Bureau of Land Management 1995]). During 1988 to 1996, summer-run steelhead observations in the Trinity River and its tributaries ranged from 20 adults to 1,037 adults (U.S. Fish and Wildlife Service et al. 2004).

Fall-run steelhead are the primary run used by Trinity River Hatchery for hatchery production. The mean estimated run size for adult fall-run steelhead in the Trinity River above Willow Creek is 13,495 fish, based on surveys conducted from 1980 to 2021 (Kier et al. 2022). Run-size estimates during this period ranged from 2,972 fish in 1998 to 53,885 fish in 2007. The 2021 estimated total run size of 7,029 fish was 52.1% of the average since 1980 (Kier et al. 2022).While the proportion of wild fish to hatchery fish varies between year, hatchery fish made up greater than 50% of the steelhead run observed since 1980 (Kier et al. 2022).

Winter-run steelhead spawning escapement in the Trinity River is highly variable. Between 1980 and 2002, run size estimates upstream of Willow Creek based on weir counts ranged from 2,750 to 33,700 fish and averaged 9,400 fish (U.S. Fish and Wildlife Service et al. 2004). It is noted that weir counts typically only capture a portion of the winter-run steelhead since the weirs are removed or inoperable during high river flows (U.S. Fish and Wildlife Service et al. 2004). Recent monitoring of Trinity River salmon and steelhead escapement based on mark-recapture methods, do not include escapement estimates for winter-run steelhead since the weirs and traps are often inoperable throughout the winter (e.g., Kier et al. 2021, 2022).

Green Sturgeon, Northern DPS

The northern DPS of the North American green sturgeon occurs in the Trinity River Region; however, data from the Trinity River are limited, so most information on life history characteristics for green sturgeon in the Trinity River are based on data from the Klamath River. Green sturgeon are long-lived fish with an expected life span of at least 50 years. They reach maturity around age 16 and typically spawn once every four years (Klimley et al. 2007). Surveys of adult green sturgeon in the Klamath River found fish ranging in age from 16 years to 40 years (Van Eenennaam et al. 2006). Adult migration occurs from March through July, and while spawning can also take place from March through July, most spawning taking place from the middle of April to the middle of June (National Research Council 2004). Green sturgeon are known to spawn in the lower section of the mainstem Trinity River from the confluence with the Klamath River upstream approximately 43 miles to Gray's Falls near Burnt Ranch. Green sturgeon adults enter the Trinity River from the Klamath River Estuary as early as February to make their way upstream to spawn from the lower section of the mainstem Trinity River to the confluence with the Klamath River upstream approximately 43 miles to Gray's Falls near Burnt Ranch. After spawning, most green sturgeon hold in mainstem pools until the onset of fall rainstorms and increased river flow, when they move downstream and leave the river system (Benson et al. 2007). Approximately 25% of green sturgeon migrate directly back to the ocean after spawning (Benson et al. 2007), but freshwater residency may last up to 199 days (Moyle 2002; Section O.1.3.2.5, *Green Sturgeon, Northern DPS*).

Green sturgeon broadcast spawn in deep pools, where females release their eggs which adhere to gravel substrates. Northern DPS green sturgeon eggs hatch approximately a week after fertilization, and optimal temperature for incubation range from 51.8–71.6°F (Eenennaam et al. 2005). The larval period is considered to be March through September. The juvenile stage of green sturgeon begins when metamorphosis of the larva is complete, typically about 45 days

after hatching and approximately up to 2 cm TL. Juveniles (up to 150 cm TL) typically slowly migrate downstream, and rear in the lower Klamath River for up to a year or until approximately their first summer, with optimal growth temperatures ranging from 59–66.2°F (Moyle 2002; Mayfield and Cech, Jr. 2004). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near Burnt Ranch to the Klamath River Estuary (Section O.1.2.5.1, *Green Sturgeon, Northern DPS*). Juvenile green sturgeon likely begin to out-migrate from the Trinity River during their first summer, based on observations near Willow Creek, and optimal growth temperatures range from 59–66.2°F (Moyle 2002; Mayfield and Cech, Jr. 2004). After moving downstream, juvenile green sturgeon may rear in larger river sections, such as the lower Klamath River, or in the Klamath River Estuary for another year or two before they migrate to the Pacific Ocean (National Research Council 2004; Federal Energy Regulatory Commission 2007; Israel and Klimley 2008).

Pacific Lamprey

Pacific lamprey are an anadromous species important to local tribes which supports a subsistence fishery on the lower Trinity River. Adult Pacific lamprey may begin their upstream migration during all months of the year, but peak upstream migration typically occurs from December through June (Larson and Belchik 1998; Petersen Lewis 2009).

In general, adult Pacific lampreys have two life history types: ocean maturing where individuals likely spawn several weeks after entering freshwater, and stream maturing where individuals spend one year in freshwater prior to spawning (Clemens et al. 2013; Parker et al. 2019). In general, adult Pacific lamprey hold in protected areas with large cobble, boulders, bedrock crevices, glides, runs, and riffles (Lampman 2011). Water temperature requirements for holding adult Pacific lampreys have not been fully evaluated, but have been observed in water temperatures from 60 - 84°F (Starcevich et al. 2014). After entering freshwater, Pacific lamprey hold through summer and most of the winter before reaching sexual maturity. Pacific lamprey undergo a secondary migration in the late winter or early spring from holding areas to spawning grounds; spawning typically occurs from March through June when daily mean water temperatures range from 50–64°F, with peak spawning typically occurring in April and May and when water temperatures are approximately 57–59°F (Stone 2006; Brumo et al. 2009; Robinson and Bayer 2005; Clemens et al. 2012; Lampman 2011).

Redds are typically constructed in gravel and cobble substrates within pool and run tailouts and low gradient riffles (Stone 2006; Brumo et al. 2009). Eggs are deposited in the redd and hatch after approximately 15 days, depending on water temperatures, and egg-sac larvae then spend another 15 days in redds before emergence (Meeuwig et al. 2005; Brumo 2006). Temperatures in excess of 65°F during incubation have been shown to reduce embryo survival (Meeuwig et al. 2005).

After emergence from redds, eyeless Pacific lamprey larvae, known as ammocoetes, settle out of the water column and burrow into fine silt and sand substrates in depositional areas that often contain organic matter. Ammocoetes rear in these habitats for 4–10 years, and have been observed burrowed in substrates in streams with water temperatures up to 80°F (Claire 2004), with upper temperature tolerances estimated at 83°F (Whitesel and Uh 2022). After Pacific lamprey metamorphose to the macropthalmia stage, individuals migrate to the ocean typically in conjunction with high flow events between fall and spring, but can occur year-round.

Pacific lamprey in the Klamath River Basin, including Trinity River, are a part of the California North Coast Regional Management Unit identified by the USFWS (Boyce et al. 2022). Limited data are available on the distribution and abundance of Pacific lamprey in the Trinity River. They are expected to have a distribution similar to anadromous salmonids that use the mainstem Trinity River and accessible reaches of larger tributaries. Pacific lamprey abundance in the Trinity River is expected to be declining based on information from tribal fishermen who catch lamprey in the lower Klamath River (Petersen Lewis 2009). Parallels in the lifecycles of Pacific lamprey and salmonids make them susceptible to many of the same factors as salmon and steelhead. Reduced access to historical spawning and rearing habitats in the Trinity River above Lewiston Dam, degraded spawning and rearing habitat resulting from operations of dams and water diversions, impacts from historical mining practices, and predation by nonnative invasive species (e.g., brown trout) have likely contributed to adverse effects on the Trinity River Pacific lamprey population.

Brown Trout

Brown trout (*Salmo trutta*) is an introduced non-native and naturally reproducing species in the Trinity River. The species was first introduced into the Trinity River in 1883, and introductions continued intermittently in the watershed, including Trinity Reservoir, until 2008 (Sullivan and Hileman 2018) to support a recreational fishery. Brown trout are present below Lewiston Dam (Upper Trinity River), which is the terminal end of upstream migration. Sullivan and Hileman (2018) noted that the abundance of brown trout in the Trinity River has declined in recent years after peaking in 2004.

It is uncertain to what degree the species is anadromous in the Trinity River, while this species is capable of migrating from the ocean to freshwater, spawning, and returning to the ocean, there appears to be generally lower numbers of brown trout in the lower Trinity and lower Klamath rivers, as compared to the upper Trinity River closer to the Lewiston Dam. In the lower Trinity River, brown trout have been captured at the Willow Creek Weir (39 trout over 1,618 trap days) between 1989 and 2017 (M. Kier, CDFW Environmental Scientist, personal communication 2017, as cited in Sullivan and Hilemean 2018). The presence of brown trout in the Klamath River is uncommon, as no brown trout were observed during the creel censuses conducted from 1997 and 2017 from the mouth of the Klamath River to Weitchpec (S. Borok, Environmental Scientist, CDFW personal communication 2017, as cited in Sullivan and Hilemean 2018). The predominant life history of brown trout in the Trinity River may be considered a riverine (potamodromous) population, where the entire life history occurs in freshwater—young are born in upstream freshwater, juveniles migrate further downstream in freshwater, and following maturity into adults migrate back upstream to spawn (Sullivan and Hilemean 2018).

Brown trout can live to nine years old (as documented in California), can reach 3.4 feet long, and are notably distinguished by their elongated shape, brown or yellowish hue, and dark spots often surrounded by a pale halo. The brown trout's diet changes depending its size—small trout feed mostly on drift organisms (terrestrial insects), as they grow larger than 9 inches, their diet extends to fish, crayfish, and dragonfly larvae, and once greater than 16 inches their diet is almost exclusively fish (Moyle 2002). Diet estimates from the Trinity River determined that brown trout (particularly large brown trout) primarily forage on hatchery fish, followed by invertebrates, wild salmonids, and lamprey (Alverez 2017). Brown trout are parasitized on by

native Klamath River lamprey (*Entosphenus similis*) (Alvarez 2017; Sullivan and Hilemean 2018).

Aquatic Habitat

Spawning and rearing habitat for native anadromous fish extends from Lewiston Dam downstream throughout the Trinity River to its confluence with the Klamath River. Impacts from Trinity and Lewiston dams on spawning and rearing habitat are greatest near the Lewiston Dam. The TRRP was specifically created to improve aquatic habitat conditions for salmon and steelhead, with a focus on the 40-mile reach from Lewiston Dam downstream to the North Fork Trinity River confluence. Since inception in 2000, the TRRP has implemented a variety of restoration actions to improve aquatic habitat conditions in the Trinity River that include: flow management, channel rehabilitation, sediment management, watershed restoration, and adaptive management.

Fish Passage

Construction of Trinity and Lewiston dams was completed in the early 1960s and blocked access to over 100 miles of spawning and rearing habitat for native anadromous fish. No fish passage has been provided around the dams and suitable habitats still exist upstream of the dams. There are no other major dams or diversions on the Trinity River downstream of Lewiston Dam.

Hatcheries

The Trinity River Hatchery was established immediately downstream of Lewiston Dam to mitigate for the loss of salmonid production upstream of the Lewiston and Trinity dams (Bureau of Reclamation 2008). The hatchery is funded by the Bureau of Reclamation (Reclamation) and operated by the CDFW to produce coho salmon, spring-run and fall-run Chinook salmon, and steelhead. An HGMP for the Trinity River Hatchery was approved in 2019 and implementation was initiated in 2021 (Hoopa Valley Tribe et al. 2022). The hatchery releases approximately 300,000 yearling coho salmon annually from March 15 to May 15. Currently, all coho salmon are produced from endemic (derived from Upper Trinity River population) coho salmon broodstock. All juvenile Chinook salmon and steelhead are produced from in-river (hatchery and endemic) broodstock. The hatchery has a goal of releasing one million sub-yearling spring-run Chinook salmon in May and 400,000 yearlings in October, while the goal for fall-run Chinook salmon is to release two million sub-yearlings in June and 900,000 yearlings in October. The goal for steelhead is to release 448,000 yearlings in mid-April (Rubert pers. comm.).

Predation

Brown trout, which are native to Europe and North Africa, were brought to North America and transplanted widely during the mid- to late 1800's and were eventually introduced into the Trinity River in the 1890s (Alverez 2017). Brown trout plantings in the Trinity River continued into the 1930s and a self-sustaining brown trout population has persisted in the Trinity River through to present (Alverez 2017). Brown trout are well-documented as piscivorous predators, with prey fish becoming a larger proportion of their diet as they grow. In the Trinity River, Brown trout transition from a diet composed mostly of small drift invertebrates to a diet composed mostly of fish and larger macroinvertebrates at approximately 3–5 years of age (30-50 centimeters [cm] fork length) (Alverez 2017).

Concerns regarding the potential negative effects of predation by brown trout on salmon and steelhead populations in the Trinity River date back to the early 1900s (Alverez 2017). More recently (i.e., 1980s to 2010s), decreases in listed salmonid populations and increases in brown trout observations heightened concerns that predation on juvenile salmon and steelhead by brown trout could be a major negative impact on native fish populations in the Trinity River, particularly federally listed coho salmon (National Marine Fisheries Service 2014b; Alverez 2017).

Studies by Alverez (2017) investigated brown trout population characteristics and feeding behavior in the Trinity River to assess their potential impact on native salmon and steelhead populations. In the 40-mile study reach from Lewiston Dam to the confluence with the North Fork Trinity River, Alverez (2017) estimated a population of 1,579 brown trout >20 cm. Juvenile salmonids made up a substantial proportion of the diet of brown trout and hatchery fish composed about 6-times the biomass (5,930 kilograms [kg]) compared with wild fish (924 kg). Consumption level estimates suggest that predation by brown trout could pose an impediment to the recovery of native salmon and steelhead populations in the Trinity River. In response to concerns about predation by brown trout on juvenile salmon and steelhead, CDFW has adjusted sportfishing regulations to reduce the number of brown trout in the Trinity River by increasing the daily bag limit increasing from one in 2005 to ten in 2023 (Alverez 2017; California Department of Fish and Wildlife 2023a).

O.1.2.6 Lower Klamath River From Confluence With Trinity River to Pacific Ocean

The lower Klamath River flows for approximately 43 miles from the confluence with the Trinity River near Weitchpec to the Pacific Ocean. The Trinity River is the largest tributary of the Klamath River and provides a substantial amount of flow to the lower Klamath River. Salmonids primarily use this section of the Klamath River as a migration corridor to access spawning and rearing habitat located in the Trinity River basin and the Klamath River basin upstream of the confluence with the Trinity River, or in other large tributaries (e.g., Blue Creek) that enter the lower Klamath River.

In April 2017, Reclamation signed a Record of Decision for a long-term plan to protect adult salmon in the Lower Klamath River (U.S. Department of Interior 2017). The long-term plan was developed following a massive die-off of approximately 34,000 anadromous salmonids during a two-week period in the lower Klamath River in September 2002. This 2002 fish die-off was attributed to two fish disease pathogens that rapidly spread through the population due to high fish densities, low flows, and relatively high water temperatures. The long-term plan will provide supplemental flows between mid-August and September from Lewiston Dam on the Trinity River when the flow in the Lower Klamath River is projected to be less than 2,800 cfs. The flow augmentation will be implemented based on real-time environmental and biological monitoring and include three components: (1) preventative base-flow release to increase the base-flow of the lower Klamath River to 2,800 cfs to improve environmental conditions (2) a one-day preventative pulse flow targeting 5,000 cfs in the lower Klamath River to alleviate continued poor environmental conditions and signs of disease; and (3) a five-day emergency pulse flow targeting 5,000 cfs in the lower Klamath River to avoid a significant die-off of adult salmon when the first two components are not successful.

Fish in the Lower Klamath River From the Trinity River Confluence to the Pacific Ocean

Focal fish species that occur in the lower Klamath River include all those described in Section O.1.2.5, *Trinity River from Lewiston Dam to the Confluence with Klamath River*, as well as eulachon and coastal cutthroat trout.

Eulachon

The southern DPS of eulachon was listed as a threatened species under the ESA in 2010 (75 FR 13012) due to abrupt declines in abundance throughout their range (NMFS 2017). In 2016 and 2022, the ESA five year reviews reaffirmed the southern DPS status as threatened. Critical habitat was designated on October 20, 2011 (76 FR 65324), and the southern DPS of eulachon is comprised of fish that spawn in coastal rivers from south of the Nass River in British Columbia to the Mad River in California (National Marine Fisheries Service 2017a).

Eulachon are an anadromous smelt species that are important to local tribes and once supported a subsistence fishery on the lower Klamath River. The spawning migration period for adult eulachon in the Klamath River begins in December and continues until May, with peak migration occurring in March and April (Yurok Tribal Fisheries Program 1998; Larson and Belchik 1998). Eulachon can become sexually mature at 2 years but spawning typically occurs at ages 3, 4, or 5 (Scott and Crossman 1973). Spawning occurs in the lower reaches of rivers and tributaries. Eulachon are broadcast spawners most commonly over sand, though spawning substrates can range from silt, sand or gravel to cobble and detritus (California Department of Fish and Game 2010; National Marine Fisheries Service 2017a). Eulachon usually die after spawning.

Although specific spawning areas are unknown, adult eulachon are generally observed only in the lower 24 miles (40 kilometers [km]) of the Klamath River, except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Eulachon eggs hatch in 20 to 40 days depending on water temperature, with cooler temperatures leading to longer incubation times. Spawning is reported to occur at temperatures from 4 to 10°C; colder temperatures may stop migration (National Marine Fisheries Service 2017a). Once they hatch, larval eulachon are carried out to the ocean by river currents (Scott and Crossman 1973), remaining in the Klamath River for only about 5 days until they are washed out to sea. Larvae live on their yolk sac reserves after hatching —they do not feed while in fresh water (Gustafson et al. 2022). The larval period is considered to be January through June.

Historically, eulachon were abundant in the lower Klamath River, based on accounts from Yurok Tribal elders. Documented landings data are limited. Based on the NMFS Recovery Plan (National Marine Fisheries Service 2017a), the only reliable landings data are for 1963 when 650,000 fish were reported landed from the lower Klamath River. Noticeable runs of eulachon were observed by Tribal fishers in 1988 and 1989, and a eulachon was incidentally captured at the mouth of the Klamath River in 1996 (Larson and Belchik 1998). More recently, eulachon were documented in the Klamath River during the spawning seasons of 2011 to 2014, with abundance peaking during 2013 to 2014 return years (National Marine Fisheries Service 2017a). Based on the NMFS 5-year status review (National Marine Fisheries Service 2022), surveys of eulachon abundance in the lower Klamath River have not been conducted since 2014, however, in each year since low numbers of individuals have been observed at the mouth of the Klamath River.

Coastal Cutthroat Trout

Coastal cutthroat trout (*Oncorhynchus clarki clarki*) is listed as a CDFW Species of Special Concern and a USDA Forest Service Sensitive Species. In a 1999 status review, NMFS determined that the Southern Oregon/California Coasts ESU did not warrant ESA listing (Johnson et al. 1999).

Coastal cutthroat trout occur in California throughout low-gradient coastal streams and estuaries from the Eel River to the Oregon border, with an inland extent of 5 miles and 30 miles, respectively. Within the lower Klamath River, coastal cutthroat trout are distributed primarily within smaller tributaries along the lower 22 miles of Klamath River mainstem (National Research Council 2004). The limited extent of coastal cutthroat in the Trinity seems constrained to tributaries. Moyle et al. (1995) identified their presence in tributaries and they were observed during 1989–1991 dive surveys, in Horse Linto Creek, a tributary to the Trinity River about 68 miles upstream from the mouth of the Klamath River (D. Fuller, Six Rivers National Forest, personal communication, as cited in Gerstung 1997). Coastal cutthroat trout are not identified on the Trinity River on CDFW Biogeographic Information and Observation System (BIOS) California Native Fish Species by Watershed layer (BIOS 2019) or the Coastal Cutthroat Trout Range layer (BIOS 2014).

While not well studied, coastal cutthroat trout in the lower Klamath, and presumably lower Trinity tributaries, include both resident and amphidromous (returns to and from the ocean multiple times) life histories. The species also has the capability to be lacustrine (migrating from a lake, while not noted in California) and riverine (migrating between different locations within the river). Coastal cutthroat trout typically live less than 7 years, can reach 1.6 feet long, and are distinguished by their numerous black body spots and yellow to red marks on the underside of each lower jaw. The coastal cutthroat trout's diet changes depending its size—small trout feed mostly on benthic and drift organisms, micro-crustaceans, and occasionally smaller fish, and as they grow larger, they become more piscivorous and prey on sculpin, and juvenile salmon and trout (Moyle 2002).

Exact coastal cutthroat populations are difficult to determine because juveniles and even some migrating adults may be mistaken for steelhead. Records suggest that populations of coastal cutthroat trout in California have likely declined historically due to habitat alterations from logging, grazing, agriculture, or other human activities including increased upstream erosion filling in estuaries and then further alterations by dredging for boat access (Moyle 2002).

Current populations of coastal cutthroat trout in California are small, fragmented, and face pressures including current and historical land use as well as predicted effects of climate change (Moyle et al. 2017).

Aquatic Habitat

Adult salmon, steelhead, and Pacific lamprey primarily use the Lower Klamath River as a migration corridor to reach spawning and rearing habitats upstream or in tributaries. This reach is used by sturgeon for holding, spawning, and rearing. It is also used by eulachon as a migration corridor for spawning adults, rearing of hatched larvae, and for emigration of juveniles.

Summer water temperatures can become stressful and approach lethal levels for native salmonids and also promote infection and disease. Flow releases from Trinity River are used periodically to reduce water temperature and disease in the Lower Klamath River.

O.1.2.7 Harvest

Ocean harvest of Klamath River fall Chinook salmon from 1986–2023 averaged 12,927 fish annually (Pacific Fishery Management Council 2024). Recreational fisheries are managed using a quota system for fish over 22 inches (i.e., adults); sub-quotas have been established for all open areas on the Klamath system. Recreational harvest of adult Klamath River Chinook salmon from 1986-2023 averages 14,165 fish per year (Pacific Fishery Management Council 2024). Creel surveys of recreational anglers in the lower Klamath River in fall 1998–2022 report an average catch of 1,498 steelhead, 2,740 Chinook, and 64 coho salmon per year (Table O-2). Creel surveys conducted in spring 2017–2022 report an average recreational angler catch of 12 steelhead and 113 Chinook salmon per year (Table O-3). In 2023, in-river harvest was limited to only Tribal fisheries, and numbers presented do not encompass all the fish harvested in the lower Klamath River each year, only the reported catch from angler surveys.

Table O-2. Recreational Angler Catch as Reported in Fall Creel Surveys of the Lower Klamath River, 1998–2022

Species	Average	Min	Max
Steelhead	1,498	9	6,452
Chinook salmon	2,740	81	7,730
Coho salmon	64	0	527
Cutthroat trout	11	0	31
Total	**4,301**	**112**	**10,837**

Source: California Department of Fish and Wildlife 2023b, 2023c.

Table O-3. Recreational Angler Catch as Reported in Spring Creel Surveys of the Lower Klamath River, 2017–2022

Species	Average	Min	Max
Steelhead	12	0	37
Chinook salmon	113	10	312
Cutthroat trout	11	0	11
Total	**124**	**10**	**314**

Source: California Department of Fish and Wildlife 2023d.

Green sturgeon were historically harvested by the Yurok Tribe. From 1982 through 1992, the average harvest of green sturgeon on the Yurok Tribe Reservation was fairly consistent, averaging just under 300 fish per year (Trinity River Restoration Program 2023b). Currently, harvest of white and green sturgeon is closed year round in the lower Klamath River. Anglers are not required to report accidental catch and releases of sturgeon.

Pacific lamprey are harvested by the Hoopa and Yurok tribes in Trinity River and Lower Klamath River and remain an integral part of their culture.

O.1.2.8 Disease

Several naturally occurring, endemic salmonid-specific pathogens occur in the Klamath River watershed: *Ceratomyxa shasta* (C. *shasta*), *Parvicapsula minibicornis* (*P. minibicornis*), *Ichthyophthirius multifis* (Ich), and *Flavobacterium columnare* (columnaris). The parasites *C. shasta* and *P. minibicornis* regularly result in substantial mortality of naturally-spawned and hatchery Klamath River salmon (Fujiwara et al. 2011; True et al. 2013), while steelhead are generally resistant to *C. shasta*. These parasites occur throughout the watershed, however, *C. shasta* and *P. minibicornis* are not found at significant levels in the Trinity River (Stocking et al. 2006). Within the Klamath River, *C. shasta*, Ich, and columnaris have been observed to result in high rates of mortality in salmon (True et al. 2017).

Both *C. shasta* and *P. minibicornis* are myxozoan parasites that spend part of their life cycle in an invertebrate host and another part in a fish host, which limits transmission of these parasites to areas where hosts are present. In the Klamath River, their invertebrate host is the annelid polychaete worm *Manayunkia speciosa* (Bartholomew et al. 1997, 2007). Once the polychaetes are infected, they release *C. shasta* and *P. minibicornis* actinospores into the water column. Actinospores are generally released when temperatures rise above 50°F and remain viable from three days to seven days at temperatures from 51.8°F to 64.4°F, with temperatures outside that range resulting in a shorter period of viability (Foott et al. 2007). Studies found that increasing parasite concentrations and water temperatures were positively associated with the proportion of juvenile fish that experienced infection and mortality (Ray et al. 2014). Despite potential resistance to *C. shasta* and *P. minibicornis* in native populations, salmon exposed to high levels of those parasites may be more susceptible to disease—particularly juvenile salmon, experiencing higher (>59ºF) water temperatures (Ray et al. 2014).

Ich, a protozoan parasite that spreads horizontally from fish to fish, and columnaris have occasionally had a substantial impact on adult salmon within the Klamath drainage, particularly when habitat conditions include exceptionally low flows, high water temperatures, and high densities of fish (California Department of Fish and Game 2004). For adult salmon the effects of Ich and columnaris are generally not as harmful as the observed effects of the myxozoan parasites on juveniles, although under some conditions substantial fish mortality can occur as a result. The 2002 fish kill in the Lower Klamath River provided dramatic evidence of the ability of Ich and columnaris to cause adult salmon mortality, with more than 33,000 adult salmon and steelhead lost during a disease outbreak (California Department of Fish and Game 2004). Most of the fish affected by the 2002 fish die-off were fall-run Chinook salmon in the lower 36 miles of the Klamath River (California Department of Fish and Game 2004). Environmental conditions in the river at the time of the 2002 fall-run Chinook salmon run were characterized by low flow rates, warm water temperatures, and an apparent lack of migration cues for the fish to proceed upriver.

O.1.3 Sacramento River

Aquatic resources in the Sacramento River are affected by the habitat along the river and along the tributaries that connect to the river. Habitat along the river ranges from artificial structures used for water supply and flood management to open spaces that provide more natural types of habitat. The flow regime of the Sacramento River is managed for water supply and flood management, as described in Appendix H, *Water Supply Technical Appendix*. The following discussion focuses on the fish and aquatic habitat conditions in the Sacramento River.

O.1.3.1 Water Operations Management

Flow

Inflows to Shasta Reservoir come from the Sacramento, Pitt, and McCloud rivers. Releases from Shasta Reservoir and imports from the Trinity River Basin flow into Keswick Reservoir, impounded by Keswick Dam.

The measurement of flows on the Sacramento River at Bend Bridge captures tributary inflows upstream of the Red Bluff Pumping Plant and upstream of most diversions under Sacramento River Settlement Contracts (e.g., inflows from Clear Creek, Battle Creek). Flood flows are diverted into the Sutter Bypass at Colusa Weir and Tisdale Weir. The Sacramento River near Wilkins Slough is upstream of the Feather River confluence, this location is used to measure local diversion flows in the vicinity at the Sacramento River with navigation criteria and represents the approximate downstream extent of diversion under Sacramento River Settlement Contracts. A portion of the runoff and drainage on the west side of the Sacramento Valley returns to the Sacramento River at the Knights Landing Outfall Gates from the Colusa Basin Drain. The Sacramento River at Verona captures flow downstream of the Feather River and downstream of the Fremont Weir diversion into the Yolo Bypass where it joins the remainder of the flows from the Colusa Basin Drain through the Ridge Cut and passes Wallace Weir. Flows diverted into the Yolo Bypass and past Freeport are addressed in the Delta watershed.

Reclamation operates and maintains the Shasta Division of the CVP for flood control and navigation, municipal and industrial (M&I) and agricultural water supplies, fish and wildlife, hydroelectric power generation, Sacramento River water quality, and Delta water quality. Facilities include the Shasta Dam and Power Plant, Keswick Dam and Power Plant, and a Temperature Control Device (TCD) on the upstream face of Shasta Dam. Major facilities in the Sacramento Division of the CVP include the Red Bluff Pumping Plant, the intake for the Tehama-Colusa Canal and the Corning Canal. Additional information on seasonal operations on the Sacramento River can be found in Chapter 3, *Alternatives*.

Water Temperature

Reclamation operates a TCD on Shasta Dam primarily for the protection of winter-run Chinook salmon during egg incubation in the summer. Under Water Board Order 90-5, Reclamation must meet 56°F at Red Bluff Diversion Dam unless: (1) daily average water temperatures higher than 56°F will be detrimental to the fishery: and (2) factors beyond the reasonable control of Reclamation prevent maintaining 56°F as the Red Bluff Diversion Dam. These factors include conditions where: (1) protection of the fishery can best be achieved by allowing a higher temperature in order to conserve cool water for later release: and (2) allowing a higher water temperature is necessary to implement measures to conserve winter-run Chinook salmon. Zeug et

al. (2023) reviewed the laboratory and field data used as inputs to estimate survival of winter-run Chinook salmon during egg incubation. There is uncertainty associated with both data sources and assumptions necessary to make model predictions. Authors reported finding significant uncertainty in the data used to parameterize temperature-egg survival models, likely the effect of collection purpose: laboratory data were collected to evaluate survival under differing but constant temperatures, field data consists of five separate model inputs each with a level of uncertainty used in aggregate to estimate egg survival. Similar analyses in Attachment L.2, *Egg-to-fry Survival and Temperature-Dependent Mortality*, describe uncertainties associated with data sources and assumptions. There may be other stressors besides temperature contributing to mortality as shown by low numbers of surviving fish collected at the Red Bluff screw traps during years where there were favorable water temperatures in the spawning reaches of the Sacramento River.

O.1.3.2 Upper Sacramento River from Keswick Dam to the Delta

The Sacramento River extends from Keswick Dam and Reservoir, the afterbay for Shasta Reservoir, for approximately 240 miles to the Delta. The Sacramento River, the largest river in California, and its tributaries provide spawning, rearing, and migratory habitat for four races of Chinook salmon, Central Valley steelhead, and two species of sturgeon. Winter-run and spring-run Chinook salmon are Federal- and state-listed species and Central Valley DPS of steelhead and Southern DPS for North American green sturgeon are Federally listed. The river also supports several native species, including Sacramento splittail, and Pacific lamprey, as well as non-native species including striped bass and American shad.

Fish Evaluated in the Sacramento River

The analysis is focused on the following species:

- Winter-run Chinook salmon, Sacramento River ESU
- Spring-run Chinook salmon, Central Valley ESU
- Steelhead, California Central Valley DPS
- Green sturgeon, Southern DPS
- Fall- and late fall-run Chinook salmon, Central Valley ESU
- White sturgeon
- Native Minnows (Sacramento splittail, hardhead, Sacramento hitch)
- Pacific lamprey
- Western river lamprey
- American shad
- Threadfin shad
- Striped bass
- Black basses (largemouth, smallmouth, spotted)

Winter-run Chinook Salmon, Sacramento River ESU

NMFS under an emergency interim rule listed the Sacramento River winter-run Chinook salmon ESU as a threatened species in August 1989 (54 FR 32085). In 1994, NMFS reclassified the ESU as endangered due to several factors, including the continued decline and increased variability of run sizes including expected weak returns due to small year classes in 1991 and 1993, and continuing threats to the species (59 FR 440). The ESU consists of one population in the mainstem of the upper Sacramento River in California's Central Valley below Keswick Dam, though efforts to reintroduce the run in Battle Creek have had success in recent years with at least 700 subadults and adults returning in 2020 as a result of juvenile releases undertaken in 2018 and 2019 (U.S. Fish and Wildlife Service 2020). NMFS reaffirmed the listing of the Sacramento River winter-run Chinook salmon ESU as endangered on June 28, 2005 (70 FR 37160), and expanded the ESU to include winter-run Chinook salmon produced by the Livingston Stone National Fish Hatchery (LSNFH) artificial propagation program in the ESU.

Adult winter-run Chinook salmon return to freshwater during winter but delay spawning until spring and summer. Adults enter freshwater in an immature reproductive state, similar to spring-run Chinook salmon, but winter-run Chinook salmon move upstream much more quickly and then hold in the cool waters downstream of Keswick Dam for an extended period before spawning. Juveniles spend about five months to eight months in the river and estuary systems before entering the ocean. This life-history pattern differentiates the winter-run Chinook salmon from other Sacramento River Chinook salmon runs and from all other populations within the range of Chinook salmon (California Department of Fish and Game 1985, 1998).

Access to the majority of historical winter-run Chinook salmon habitat has been blocked by dam construction (Bureau of Reclamation 2008). The remaining accessible habitat occurs in the Sacramento River downstream of Keswick Dam and in Battle Creek. In addition, juveniles have also been found to rear in the lower American River, lower Feather River, Mill Creek, Deer Creek, and the Delta before emigrating to the ocean (Phillis et al. 2018). The Battle Creek Salmon and Steelhead Restoration Project has released 567,412 juvenile winter-run Chinook salmon to the creek since 2018 (National Marine Fisheries Service 2021a) and between 21 and 942 adults have returned to the creek each year during 2019 through 2022 (Azat 2023). NMFS (2021a) indicated that successful spawning of these adults occurred in 2020.

Central Valley-wide escapement data indicate that the winter-run Chinook salmon population declined from levels in the 1970s to relatively low levels through the 1980s and 1990s, with a moderate, six-year rebound in the early 2000s (Azat 2023). The population dropped again in the late 2000s and 2010s but has trended upward since 2017 and surpassed 10,000 adults in 2021 for the first time since 2006.

Adult winter-run Chinook salmon enter the San Francisco Bay in November and migrate upstream past the former location of the Red Bluff Diversion Dam (RBDD) beginning in mid-December and continuing into early August. Most of the run passes RBDD from January to May, with the peak in mid-March (Hallock and Fisher 1985). Holding occurs in the upper 10 to 15 river miles (RM) of the Sacramento River below Keswick Dam for up to eight months (National Marine Fisheries Service 2011b; Windell et al. 2017).

Aside from the recent addition of Battle Creek, winter-run Chinook salmon spawn only in the Sacramento River, almost exclusively above RBDD, with the majority spawning upstream of the Clear Creek confluence (California Department of Fish and Wildlife Aerial Redd Survey 2021 unpublished data). Aerial redd surveys have indicated that the winter-run Chinook salmon spawning distribution has shifted upstream since gravel was installed in the upper river near Keswick Dam; a high proportion of winter-run Chinook salmon spawn on the recently placed gravel (U.S. Fish and Wildlife Service and Bureau of Reclamation 2008). Spawning occurs April through August, with the peak between May and July (Hallock and Fisher 1985; Fisher 1994).

Fry emergence occurs primarily from July through October (Yoshiyama et al. 1998) and fry disperse to areas downstream for rearing. Juvenile migration past RBDD may begin in late July, peaks during the fall, and can continue until mid-March in drier years (Vogel and Marine 1991). The majority of juveniles emigrate past RBDD as fry and rear in the river downstream of RBDD (Martin et al. 2001). Juveniles typically migrate past Knight's Landing once flows at Wilkins Slough rise to about 14,000 cfs (del Rosario et al. 2013). Juveniles enter the Delta primarily during December through April and most juveniles emigrate past Chipps Island by the end of April (U.S. Fish and Wildlife Service unpublished Data).

Additional details on topics related to winter-run Chinook salmon management can be found on agency websites and in several chapters, attachments, and appendices of this EIS: (1) instream flow management in Sacramento River (Chapter 3, *Alternatives*); (2) operations of the Temperature Control Device (Appendix C, *Facility Description and Operations*): (3) gravel and habitat improvement projects downstream of Keswick Dam (Section O.1.3.4, *Aquatic Habitat, Spawning Habitat, Spawning Habitat Availability*): (3) Coldwater pool management in Shasta Reservoir (Chapter 3, *Alternatives*); (4) estimated winter-run egg mortality (Attachment L.2), (5) JPE (available online at https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/california-central-valley-water-operations-biological);and (7) JPI (Attachment L.3, *Winter-run Chinook Salmon Juvenile Production Index Model*), RBDD rotary screw trap monitoring and production/survival estimates (available online at: https://www.fws.gov/ and https://www.cbr.washington.edu/sacramento/data/query_redbluff_daily.html).

Spring-run Chinook Salmon, Central Valley ESU

The Central Valley spring-run Chinook salmon ESU was listed as threatened under the ESA in 1999 because of the reduced range and small size of remaining spring-run Chinook salmon populations (64 FR 50393). On June 28, 2005, NMFS published the final hatchery listing policy (70 FR 37204) and reaffirmed the threatened status of the ESU (70 FR 37160). The ESU consists of naturally spawned spring-run Chinook salmon originating from the Sacramento River and its tributaries, and also from the Feather River Fish Hatchery spring-run Chinook salmon Program (National Marine Fisheries Service 2016a).

Historically, spring-run Chinook salmon in the Sacramento River basin were found in the upper and middle reaches (1,000 to 6,000 feet) of the American, Yuba, Feather, Sacramento, McCloud and Pit rivers, as well as smaller tributaries of the upper Sacramento River downstream of present-day Shasta Dam (National Marine Fisheries Service 2009a). Estimates indicate that 82% of the approximately 2,000 miles of salmon spawning and rearing habitat available in the mid-1800s are unavailable or inaccessible today (Yoshiyama et al. 1996). Independent populations of spring-run Chinook salmon inhabit Butte Creek, Mill Creek, and Deer Creek, with repopulation

of a historically independent population in Battle Creek occurring; dependent populations occur in Antelope Creek, Big Chico Creek, Clear Creek, and Cottonwood/Beegum Creek (National Marine Fisheries Service 2016a). The migratory life stages of individuals in these waterways must pass through the Sacramento River and Delta to and from the ocean.

Spring-run Chinook salmon abundance in the Sacramento River mainstem has declined sharply, with escapement estimates ranging from approximately 3,000 to 23,000 fish during the 1970s and 1980s, 128 to 4,200 fish during the 1990s, 0 to 621 fish during the 2000s, and 0 to 466 between 2010 and 2022 (Azat 2023). However, the criteria for run classification at RBDD have changed, likely confounding conclusions regarding changes in spring-run Chinook salmon numbers in the Sacramento River. Chinook salmon expressing spring-run timing have spawned in the mainstem Sacramento River between RBDD and Keswick Dam from August through October in nine of the last 13 years (2010-2022; Azat 2023). High water temperature during spawning and egg/alevin incubation is potentially a major stressor for spring-run Chinook salmon spawning in the Sacramento River. The river currently serves primarily as a migratory corridor for the adult and juvenile life stages of spring-run Chinook salmon from the river's tributaries.

Upstream adult migration of spring-run Chinook salmon in the upper Sacramento River typically extends from mid-March through July with peak migration in late May and early June (California Department of Fish and Game 1998). Individuals enter freshwater as immature fish and hold in deep cold pools near spawning areas until they are sexually mature. Spawning occurs from late-August through October and fry emerge from November through March (Williams 2006).

Spring-run Chinook salmon juveniles show two rearing patterns in natal tributaries: (1) the majority of spring-run Chinook salmon juveniles exit tributaries and emigrate through the Sacramento River and the Delta in the spring; and (2) a very small proportion of juveniles over-summer in natal habitats and exit with the first rainstorms on the fall or winter following their birth. As a result, emigration timing is highly variable, extending from November to June (California Department of Fish and Game 1998). Peak movement of yearling spring-run Chinook salmon in the Sacramento River at Knights Landing typically occurs in December and a peak of sub-yearling juveniles are observed in late February to April (Julienne 2019). Migratory cues, such as increased flows, increasing turbidity from runoff, changes in day length, or intraspecific competition from other fish in their natal streams, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (National Marine Fisheries Service 2009a). Spring-run Chinook salmon juveniles that remain in the Sacramento River over summer are confined to approximately 100 miles of the upper mainstem. In 2024, the Park wildfire in northern California caused damage in Mill and Deer Creeks, potentially impacting spring-run Chinook salmon spawning and rearing habitat.

Operation of Feather River Fish Hatchery (FRFH) may pose threats to spring-run Chinook salmon stock genetic integrity (National Marine Fisheries Service 1998). A large portion of Central Valley spring-run Chinook salmon is of hatchery -origin, and naturally spawning populations may be interbreeding with both fall-run/late fall–run and spring-run Chinook salmon hatchery fish. The problem has been heightened by the continued production of spring-run Chinook salmon from FRFH, especially considering reports suggesting a high degree of

introgression between spring- and fall-run/late fall–run broodstock in the hatcheries. Hatchery broodstock management has attempted to segregate the two runs; but despite these efforts, substantial hybridization has occurred, resulting in substantial genetic introgression (Clemento et al. 2014; Meek et al. 2016).

Hatchery strays are an increasing problem due to releasing a larger proportion of fish offsite (National Marine Fisheries Service 1998). The release of hatchery fish away from their natal stream source will result in the straying of some component of the release, with a direct correlation between distance from stream source and rate of straying (California Department of Fish and Game 2001a). FRFH began trucking and releasing half its spring-run Chinook salmon production into San Pablo Bay, causing high rates of straying (California Department of Fish and Game 2001a). Given the large number of juveniles released off station, the potential contribution of straying adults to rivers throughout the Central Valley is considerable (National Marine Fisheries Service 2014c).

Steelhead, California Central Valley DPS

The California Central Valley (CCV) steelhead (*Oncorhynchus mykiss irideus*) ESU was listed as a threatened species under ESA on March 19, 1998. This ESU includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin Rivers and their tributaries, including Bay-Delta (63 FR 13347). Steelhead from San Francisco and San Pablo Bays and their tributaries were excluded from this listing but were included in the Central California Coast DPS, which is also listed as threatened under the ESA. On June 14, 2004, NMFS proposed that all West Coast steelhead be reclassified from ESUs to DPSs and proposed to retain CCV steelhead as threatened (69 FR 33102). On January 5, 2006, after reviewing the best available scientific and commercial information, NMFS issued its final decision to retain the status of CCV steelhead as a threatened DPS (71 FR 834). This decision included the Coleman National Fish Hatchery and Feather River Fish Hatchery steelhead populations. These populations were previously included in the ESU but were not deemed essential for conservation and thus not part of the listed steelhead population.

On August 15, 2011, after conducting a 5-year review, NMFS issued its findings concerning the status of the CCV steelhead DPS (76 FR 50447). Based on new information, NMFS determined that the status of the DPS was worse than the previous review (Good et al. 2005), and the DPS faces an even greater extinction risk. This review found that the decline in natural production of steelhead had continued unabated since the 2005 status review, and the level of hatchery influence on the DPS corresponds to a moderate risk of extinction.

Steelhead are broadly divided into life history types, based on their state of sexual maturity at the time of river entry. Only winter-run steelhead are currently found in Central Valley rivers and streams. Presently, California Central Valley steelhead DPS are found in the Sacramento River downstream of Keswick Dam, in major tributary rivers and creeks in the Sacramento River watershed, and in major tributaries of the San Joaquin River and Delta. The DPS includes steelhead from the following propagation programs: Coleman National Fish Hatchery (CNFH), Feather River Fish Hatchery (FRFH), and Mokelumne River Hatchery (MOK). The mitigation goals for the hatcheries include releases of: 600,000 yearlings from CNFH, 450,000 yearlings from FRFH, and 250,000 yearlings from MOK (California Hatchery Policy Team 2014).

Adult California Central Valley steelhead migrate into the Sacramento River from the Delta in the late summer and throughout the winter, and into early spring. Steelhead exhibit life histories in which they spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). Due to their varying life-history strategies and iteroparity, migrating adult steelhead are difficult to monitor using the same strategies employed for Chinook salmon in the Central Valley. Historical data at the Fremont Weir have shown that adult California Central Valley steelhead migrate upstream in the Sacramento River during most months of the year, beginning in July, peaking in September, and continuing through February or March (Hallock 1989; McEwan 2001; Hallock et al. 1957). The latest records of adult steelhead migration into the Sacramento River include passage estimates based on observations at RBDD ladders between 1994–2007.[3] These data suggested that the first passage at RBDD occurs in August, and the last passage by September, prior to the dam being decommissioned in 2013.

Adult steelhead abundance in the upper tributaries of the Sacramento River are based on video/trap monitoring in Battle Creek and redd surveys in Clear Creek. Stanley et al. (2020) reported escapement estimates for Battle Creek based on video monitoring at the Coleman National Fish Hatchery barrier weir fish ladder. Estimates from 2001 through 2004 ranged from 633 to 2,035 individuals. Estimates dropped below 500 individuals from 2005 through 2019 with the exception of 2013 and 2014 when 682 and 519 adults were documented. See Section O.1.5.2, *Fish Evaluated in Clear Creek*, for abundance estimates of adult steelhead in Clear Creek.

Steelhead mostly use the Sacramento River as a migratory corridor for reaching other tributaries to spawn. Data on steelhead spawning in the mainstem Sacramento River is limited and likely restricted to the area upstream of Red Bluff (National Marine Fisheries Service 2009a). No steelhead specific spawner surveys occur in the upper Sacramento River. Data from recent surveys for the four runs of Chinook salmon have found carcasses of *Oncorhynchus mykiss* (*O. mykiss*) but the majority are thought to be resident trout adults (Killam 2022). For the Sacramento River, spawning timing was taken from historical data by Hallock (1989) which indicates spawning starts in December, peaks in February, and can last until May. Adult steelhead are iteroparous, although repeated spawning rates of anadromous individuals are considered low in populations in the Central Valley (Null et al. 2013).

Embryo incubation begins with the onset of spawning in December and likely extends into early July based on historical spawning data. Studies on steelhead egg incubation temperature have found that water temperatures between 40°F and 55°F are suitable for successful incubation and fry development (Washington State Department of Ecology 2002). Steelhead egg incubation varies with temperature and requires approximately 490 accumulated temperature units. For example, in 50°F (10°C) water, incubation would end approximately 50 days after incubation

[3] Raw data were only available on hard copies (i.e., datasheets or notebooks) that were moved to electronic ledgers by CDFW staff. Digitizing these data required review and interpretation of procedures for data collection and analysis by the CDFW (Killam pers. comm.). When information on these procedures was limited, the raw data were recorded based on what CDFW predecessors had originally reported. CDFW summaries in their Upper Sacramento River annual report supplementation materials include periodicity.

starts. Egg incubation timing is not available for the upper Sacramento River so the spawning period was used with an addition of 50 days for incubation.

Juveniles rear in freshwater habitats for one to four years before emigrating to the ocean. Both spawning areas and migratory corridors are used by juvenile steelhead for rearing prior to outmigration (National Marine Fisheries Service 2009a). Upper reaches of the Sacramento River basin appear to have the longest outmigration period detected for juveniles, with captures occurring January through December, but the rotary screw traps operate year-round at RBDD. Stationary monitoring systems designed for studying Chinook salmon have low capture efficiencies for collecting juvenile *O. mykiss* smolts, as steelhead will typically outmigrate larger and have stronger swimming abilities when compared to juvenile Chinook salmon (Eschenroeder et al. 2022). Therefore, overall abundance from these surveys should be interpreted with caution. These surveys can be useful for overall juvenile *O. mykiss* outmigration timing, but it is worth noting that most of the rotary screw traps (RBDD is the exception) are not in operation year-round, and often finish in June. Due to limitations with these monitoring strategies, there is a knowledge gap in understanding the overall proportion of the population that adopts anadromy over residency.

Green Sturgeon, Southern DPS

The North American green sturgeon (*Acipenser medirostris*) population is composed of two DPSs: the Northern DPS, which includes all populations in the Eel River and northward; and the Southern DPS, which includes all populations south of the Eel River. The Northern DPS green sturgeon currently spawns in the Klamath River in California and the Rogue River in Oregon and is designated as a Species of Concern (69 FR 19975). Only the Southern DPS is found in the Action Area.

After a status review was completed in 2002 (Adams et al. 2002), NMFS determined that the Southern DPS did not warrant listing as threatened or endangered but should be identified as a Species of Concern. This determination was challenged on April 7, 2003. NMFS updated its status review on February 22, 2005, and determined that the Southern DPS should be listed as threatened under ESA (National Marine Fisheries Service 2005). NMFS published a final rule on April 7, 2006, that listed the Southern DPS as threatened (71 FR 17757); the rule took effect on June 6, 2006. Included in the listing are the spawning population in the Sacramento River and fish living in the Sacramento River, the Delta, and the San Francisco Estuary.

In September 2008, NMFS proposed critical habitat for the Southern DPS (73 FR 52084). NMFS made a final critical habitat designation for the Southern DPS on October 9, 2009 (74 FR 52300). Designated areas in California include the Sacramento River, lower Feather River, and lower Yuba River; the Delta; and Suisun, San Pablo, and San Francisco Bays (National Marine Fisheries Service 2012). On May 21, 2009, NMFS proposed an ESA Section 4(d) rule to apply ESA take prohibitions to the Southern DPS. NMFS published the final 4(d) rule and protective regulations on July 2, 2010 (75 FR 30714).

The Sacramento River provides habitat for southern DPS of North American green sturgeon spawning, egg incubation, larval and juvenile rearing, adult holding, and foraging. Sturgeon return from the Pacific ocean to the Sacramento River to spawn about every four years. They typically prefer to spawn in deep pools averaging about 28 feet deep (National Marine Fisheries

Service 2018a). Suitable spawning temperatures and spawning substrate exist for green sturgeon in the Sacramento River upstream and downstream of RBDD (Bureau of Reclamation 2008). Although the upstream extent of historical green sturgeon spawning in the Sacramento River is unknown, the observed distributions of sturgeon eggs, larvae, and juveniles indicate that spawning occurs from Hamilton City to as far upstream as Inks Creek confluence and possibly up to the Cow Creek confluence (Brown 2007; Poytress et al. 2013, 2015). Acoustic telemetry in the upper Sacramento River has not observed adult green sturgeon above Battle Creek/Cow Creek (see Heublein et al 2009, Miller et al. 2020).

Green sturgeon adults enter the Sacramento River from the Delta as early as February and ultimately make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence (Heublein et al. 2017a). Elevated flows during the late winter and early spring months may provide an important cue for spawning green sturgeon adults to initiate their upstream migrations (Heublein et al. 2009; National Marine Fisheries Service 2018a). Green sturgeon spawn in most years from April through July, but spawn in occasional years as late as October. After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (California Department of Fish and Game 2002a, Heublein et al. 2009, 2017a, National Marine Fisheries Service 2018a). Green sturgeon eggs are believed generally to hatch about a week after fertilization (Heublein et al. 2017a). After hatching, green sturgeon larvae possess limited swimming ability and generally seek refuge in low-velocity and complex habitats, such as large cobble substrate (Kynard et al. 2005). According to field observations, green sturgeon larvae begin to disperse from hatching areas at 18 days post hatch, and dispersion is complete at about 35 days post hatch (Poytress et al. 2011, cited in Heublein et al. 2017a). They begin exogenous feeding at about 15 days post hatch. The green sturgeon spawning period is from April through July, so the larval period is considered to be April through September. The downstream distribution of green sturgeon larvae in the Sacramento River is uncertain, but is estimated to extend to the Colusa area, at RM 157 (Heublein et al. 2017a). The upstream limit is the Cow Creek confluence. The effects of flow on green sturgeon larvae and juveniles are poorly understood. There appears to be a positive relationship between annual outflow and abundance in rotary screw traps at RBDD of green sturgeon larvae and juveniles (Heublein et al. 2017a). Also, there is a positive correlation between mean daily freshwater outflow (April to July) and white sturgeon year class strength (California Department of Fish and Game 1992 and U.S. Fish and Wildlife Service 1995, cited in National Marine Fisheries Service 2018a). These relationships may result from flows transporting larvae to areas with greater food availability, dispersing larvae over a wider area, and/or enhancing nutrient availability to the Sacramento River and Delta. The green sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch and about 75 mm in length (Heublein et al. 2017a; Deng et al. 2002). It is likely that juveniles rear near spawning habitat for a few months or more before migrating to the Delta (Heublein et al. 2017a). The juveniles rear in the Sacramento River from about May through December (National Marine Fisheries Service 2017c: Appendix B). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta. The number of green sturgeon accessing the upper Sacramento River appears to have increased following the decommissioning of RBDD (Steel et al. 2019).

Green sturgeon from the Sacramento River are genetically distinct from their northern counterparts, indicating a spawning fidelity to their natal rivers (Israel et al. 2004), even though individuals can range widely (Lindley et al. 2008). Larval green sturgeon have been regularly captured during their dispersal stage at about 2 weeks of age (24 to 34 mm fork length) in rotary screw traps at RBDD (California Department of Fish and Game 2002a) and at about 3 weeks old when captured at the Glenn-Colusa Irrigation District (GCID) intake (Van Eenennaam et al. 2001).

Young green sturgeon appear to rear for the first one to two months in the Sacramento River between Keswick Dam and Hamilton City (California Department of Fish and Game 2002a). Rearing habitat condition and function may be affected by variation in annual and seasonal river flow and temperatures.

The current green sturgeon population status is unknown (Beamesderfer et al. 2007; Adams et al. 2007). Using results from acoustic telemetry and dual-frequency identification sonar studies to locate green sturgeon in the Sacramento River to derive an adult spawner abundance estimate of 2,106 fish (95% confidence interval = 1,246–2,966), Mora et al. (2018) applied a conceptual demographic structure to the adult population estimate and generated a subadult Southern DPS green sturgeon population estimate of 11,055 (95% confidence interval = 6,540–15,571), together with an estimate of 4,387 juveniles (95% confidence interval = 2,595–6,179). It should be noted that the estimate does not include spawning adults in the lower Feather or Yuba Rivers (National Marine Fisheries Service 2019), with spawning confirmed in the Feather River (Seesholtz et al. 2014). However, Battaile et al. (2023) found lower adult green sturgeon abundance numbers from 2020-2022. The model they used showed population estimates of 742, 1,286, and 1,208 for years 2020-2022, respectively.

A genetic analysis of green sturgeon larvae captured in the Sacramento River resulted in an estimate of 32 to 124 adult spawning pairs upstream of RBDD from 2002 to 2006 (Israel 2006). NMFS noted that, similar to winter-run Chinook salmon, the restriction of spawning habitat for green sturgeon to only one reach of the Sacramento River increases the vulnerability of this spawning population to catastrophic events, which is one of the primary reasons that the Southern DPS of green sturgeon was federally listed as a threatened species in 2006 (74 FR 52300–52351). However, there is evidence that green sturgeon may also spawn in the Feather River, although perhaps irregularly (Seesholtz et al. 2014).

There are currently no hatchery programs to enhance populations of sDPS green sturgeon. As part of the NMFS Green Sturgeon Recovery Plan, artificial propagation of green sturgeon was listed as a threat to the natural genotype frequencies and population equilibrium of the species (National Marine Fisheries Service 2018a).

Juvenile green sturgeon and white sturgeon are periodically, although rarely, collected from the lower San Joaquin River at south Delta water diversion facilities and other sites (National Marine Fisheries Service 2009b; Aasen 2011, 2012). Green sturgeon are salvaged from the south Delta diversion facilities and are generally juveniles greater than 10 months but less than three years old (Bureau of Reclamation 2008). NMFS (2005) suggested that the high percentage of San Joaquin River flows contributing to the Tracy Fish Collection Facility could mean that some entrained green sturgeon originated in the San Joaquin River Basin.

Because green sturgeon are protected as a threatened species under the Federal ESA, take of any kind is prohibited for the species, including recreational fishing and harvesting. Additionally, take or possession of green sturgeon anywhere within California is prohibited under CDFW regulations. Occasionally a green sturgeon will be mistakenly hooked or captured in the recreational white sturgeon fishery. When this happens, the green sturgeon must be released unharmed immediately and reported to CDFW via the Sturgeon Fishing Report Card (California Department of Fish and Wildlife 2024a).

Fall-/Late Fall-run Chinook Salmon, Central Valley ESU

The Central Valley fall- and late fall–run Chinook salmon (*Oncorhynchus tshawytscha*) ESU includes all naturally spawned populations of fall- and late fall–run Chinook salmon in the Sacramento and San Joaquin River Basins and their tributaries east of Carquinez Strait, California (64 FR 50394). On September 16, 1999, after reviewing the best available scientific and commercial information, the NMFS determined that listing Central Valley fall- and late fall–run Chinook salmon was not warranted. On April 15, 2004, the Central Valley fall- and late fall–run Chinook salmon ESU was identified by NMFS as a Species of Concern (69 FR 19975). The rationale for this determination included the following items.

- The average 5-year escapement was above 190,000 fish from natural production, although 20%–40% of these natural spawners were of hatchery origin.
- Long-term trends were generally stable or increasing, but it was unclear if natural populations were self-sustaining because of the influence of hatchery production.
- Short-term trends for San Joaquin River tributaries were stable or increasing.
- Concerns remained over impacts from high hatchery production and harvest levels, although ocean and freshwater harvest rates have been recently reduced.
- Approximately 40% to %–50% of spawning and rearing habitats have been lost or degraded.

In a subsequent five-year status review of California ESUs (76 FR 50447), NMFS concluded that several Chinook salmon populations identified through genetic sampling, should be included in the Central Valley fall- and late fall–run Chinook salmon ESU (Williams et al. 2011). This includes populations in the Napa and Guadalupe Rivers, along with future populations found in basins inclusive of the San Francisco/San Pablo Bay complex, which express a fall-run timing,

Fall-run Chinook salmon is an ocean-maturing type of salmon adapted for spawning in lowland reaches of big rivers, including the mainstem Sacramento River; the late fall-run Chinook salmon is mostly a stream-maturing type (Moyle 2002). Like spring-run Chinook salmon, adult late fall-run Chinook salmon typically hold in the river for one to three months before spawning, while fall-run Chinook salmon generally spawn shortly after entering freshwater.

The primary spawning area used by fall-run and late fall-run Chinook salmon in the Sacramento River is the area from Keswick Dam downstream to RBDD. In addition, some fall-run and late fall-run Chinook salmon spawn downstream of RBDD to approximately Princeton Ferry (U.S. Fish and Wildlife Service 2003a; California Department of Fish and Wildlife Aerial Redd Survey unpublished data 2021; Azat 2023).

Annual fall-run and late fall-run Chinook salmon escapement to the Sacramento River and its tributaries has generally been declining over the last decade, following peaks in the late 1990s to early 2000s (Azat 2023). There are five main production hatcheries that propagate the Central Valley fall-run ESU: Coleman National Fish Hatchery, Feather River Fish Hatchery, Nimbus Fish Hatchery, Mokelumne Fish Hatchery, and the Merced River Fish Facility. Studies have suggested that hatchery-produced Chinook salmon may contribute large (approximately 90%) proportions of Chinook salmon to the mixed-stock fishery along the central California coast (Barnett-Johnson et al. 2007). Hatchery fall-run escapement throughout the Sacramento and San Joaquin systems were relatively consistent at approximately 50,000–60,000 fish during 2014–2018, but has dropped below 50,000 fish from 2019-2022 (Azat 2023). In-river escapement has also dropped, from an estimated 150,724 fish in 2019 to 41,861 fish in 2022, for all Sacramento and San Joaquin River systems. The low escapement numbers and abundance forecast for Central Valley fall-run resulted in the Pacific Fishery Management Council's Salmon Technical Team closing the ocean and in-river harvest in 2023 and 2024. Sturrock et al. (2019) found that transport distance of hatchery-origin juvenile Chinook salmon to release sites had increased over time (particularly during droughts) and was strongly associated with straying rate (averaging 0%–9% vs. 7%–89% for salmon released on site vs. in the bay upstream of Golden Gate Bridge, respectively), increasing the effects of hatchery releases on natural spawners. The authors suggested that decreasing variation in release location and timing could reduce spatiotemporal buffering, narrowing ocean arrival timings and increasing risk of mismatch with peak prey production. The percentage of hatchery-origin fish released downstream of the Delta has been variable over time. For example, from the mid-1980s to 2012, the proportion of hatchery fall-run Chinook salmon juveniles released downstream of the Delta by state and federal hatcheries varied from around 20% to 60% (Huber and Carlson 2015). Similarly, from 2013 to 2017, the percentage of juvenile fall-run and spring-run Chinook salmon released by state Central Valley hatcheries downstream of the Delta varied between 24% (2016) and 60% (2013) (California Department of Fish and Wildlife 2018b).

Fall-run Chinook salmon migrate upstream past RBDD on the Sacramento River from July to December, typically spawning in upstream reaches from October through March. Late fall-run Chinook salmon migrate upstream past RBDD from August to March and spawn from January to April (National Marine Fisheries Service 2009a; Tehama-Colusa Canal Authority 2008). The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, although some may remain in freshwater and migrate as yearlings. Late fall-run Chinook salmon juveniles typically enter the ocean after seven to 13 months of rearing in freshwater, at 150 to 170 mm in fork length, considerably larger and older than fall-run Chinook salmon (Moyle 2002).

White Sturgeon

On June 19, 2024, the California Fish and Game Commission voted to approve white sturgeon as a candidate species for listing under the California Endangered Species Act with final regulatory approval on July 12, 2024. On November 29, 2023, white sturgeon was petitioned for listing as threatened under the federal ESA (San Francisco Baykeeper et al. 2023). The Central Valley population of white sturgeon mainly spawns in the Sacramento River, with secondary spawning in the San Joaquin and Feather Rivers (Heublein et al. 2017a; Moyle 2002). White sturgeon are found in the Sacramento River primarily downstream of RBDD (Tehama-Colusa Canal Authority 2008). Spawning-stage adults generally move into the lower reaches of rivers during winter prior to spawning and migrate upstream in response to higher flows to spawn from February to early June (Klimley et al. 2015; Hildebrand et al. 2016; Heublein et al. 2017a). Most spawning occurs in March and April between Knights Landing and Colusa (Jackson et al. 2016; Heublein et al. 2017a). Eggs hatch in 4-12 days depending on water temperature (Wang 1986). White sturgeon larval rearing occurs primarily in the Sacramento River and the Delta (Moyle 2002; Israel et al. 2008). After absorbing yolk sacs and initiating feeding, young-of-year (YOY) white sturgeon make an active downstream migration that disperses them widely to rearing habitat throughout the lower Sacramento River and the Delta (Israel et al. 2008; Heublein et al. 2017a). Larvae have been observed to be flushed farther downstream in the Delta and Suisun Bay in high outflow years but are restricted to more interior locations in low outflow years (Fish 2010; Heublein et al. 2017a). Larvae are periodically collected in various locations throughout the Delta in general larval fish monitoring surveys (e.g., 20-mm Townet survey) in late winter and spring, and in salvage at federal and State Delta pumping facilities, suggesting that larval distribution generally ranges from downriver of spawning habitats to the approximate downstream extent of the Delta at Chipps Island (Heublein et al. 2017a).

The population status of white sturgeon in the Sacramento River is unclear. Overall, limited information on trends in adult and juvenile abundance in the Delta population suggests that numbers are declining (Reis-Santos et al. 2008). Adults ready for spawning generally move into the lower reaches of the Sacramento River during winter prior to spawning, then migrate upstream in response to higher flows and spawn from February to early June (Klimley et al. 2015; Hildebrand et al. 2016; Heublein et al. 2017a). Most spawning in the Sacramento River occurs in March and April (Kohlhorst 1976; Heublein et al. 2017a). YOY white sturgeon make an active downstream migration that disperses them widely to rearing habitat throughout the lower Sacramento River and Delta (McCabe and Tracy 1994; Israel et al. 2008). Statistical analysis has demonstrated a positive correlation between Delta outflow and year-class index of white sturgeon collected in the San Francisco Bay Study otter trawl (Fish 2010).

There is currently no hatchery program in place to supplement the white sturgeon population, although artificially reared individuals were released from 1980-1988 to supplement the wild population (Moyle et al. 2015). Commercial aquaculture facilities have raised white sturgeon for meat and caviar since 1980.

Legal and illegal overharvest have likely affected the number of adult white sturgeon (Moyle 2002), although CDFW has changed harvest rules in 2007 and again in 2023 to increase protection of the population.

Juvenile white sturgeon are rarely collected in the CVP and SWP diversion facilities (National Marine Fisheries Service 2009b; Aasen 2011, 2012), likely due to their size and ability to swim away when they encounter salvage screens. Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Sacramento Splittail

Historically, Sacramento splittail was widespread in the Sacramento River from Redding to the Delta (Rutter 1908, as cited in Moyle et al. 2004). This distribution has become somewhat reduced in recent years (Sommer et al. 1997, 2007b). During drier years there is evidence that spawning occurs farther upstream (Feyrer et al. 2005). Adult splittail migrate upstream in the lower Sacramento River to above the mouth of the Feather River and into the Sutter and Yolo Bypasses (Sommer et al. 1997; Feyrer et al. 2005; Sommer et al. 2007b). Each year, mainly during the spring spawning season, a small number of individuals have been documented at the Red Bluff Pumping Plant and the entrance to the GCID intake (Moyle et al. 2004).

Sacramento splittail are found primarily in marshes, turbid sloughs, and slow-moving river reaches (Sommer et al. 1997, 2008), but are most abundant in moderately shallow, brackish tidal sloughs and adjacent open-water areas. They also can be found in freshwater areas with tidal or riverine flow (Moyle et al. 2004). Adult Sacramento splittail typically migrate upstream from brackish areas in January and February and spawn in freshwater, particularly on inundated floodplains when they are available, in March and April (Sommer et al. 1997, 2008; Moyle et al. 2004). In the Sacramento drainage, the most important spawning areas appear to be the Yolo and Sutter Bypasses (Moyle et al. 2004); however, some spawning occurs almost every year along inundated river edges and backwaters created by small increases in flow. Splittail spawn in the Sacramento River from Colusa to Knights Landing in most years (Feyrer et al. 2005).

Although juvenile Sacramento splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks or months of rearing in floodplain habitats along the rivers (Feyrer et al. 2006). Most juvenile Sacramento splittail move from upstream areas downstream into the Delta from April through August (Meng and Moyle 1995; Sommer et al. 2007b). Juvenile size at outmigration downstream from the Yolo Bypass was found to generally be around 30–40-mm fork length (Feyrer et al. 2006). The production and recruitment of YOY Sacramento splittail is largely influenced by extent and duration of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Sommer et al. 1997; Moyle et al. 2004; Feyrer et al. 2006). Other factors that may affect the Sacramento splittail adult population include pumping at the CVP and SWP south Delta export facilities, flood control operations and infrastructure, entrainment by irrigation diversions, recreational fishing, changed estuarine hydraulics, pollutants, and nonnative species (Moyle et al. 2004; Sommer et al. 2007b).

Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Hardhead

The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are fairly common in the Sacramento River. In other parts of their range, populations have declined or have become increasingly isolated (Moyle 2002). Hardhead also inhabit reservoirs and are abundant in a few impoundments where water level fluctuations prevent black basses from reproducing in large numbers (Moyle 2002). Hardhead tend to be absent from areas that have been highly altered (Moyle et al. 1995) or that are dominated by introduced fish species, especially centrarchids (species of the black basses and sunfish) (Moyle et al. 1995). Hardhead are omnivorous, their diet consisting mostly of benthic invertebrates and aquatic plants, but also including drifting insects. In reservoirs, hardhead also prey on zooplankton (Moyle et al. 1995).

Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986). They migrate upstream and into tributary streams as far as 45 miles (72.4 km) to spawning sites. Spawning behavior has not been documented, but it is assumed to be similar to that of the pikeminnow, which deposit their eggs over gravel-bottomed riffles, runs, and at the head of pools (Moyle et al. 1995). Spawning substrates may also include sand and decomposed granite (Wang 1986).

Hardhead larvae and juveniles likely inhabit stream margins with abundant cover and move into deeper habitats as they grow larger. Adults occupy the deepest part of pools. Juvenile and adult hardhead are present in the Sacramento River year-round. Thompson et al. (2012) found that adults tend to prefer water temperatures near 67°F (19.4°C), but were frequently observed between 57.2-78.8°F (14°C-26°C), and individuals have been captured at RBDD, where water temperatures are generally much cooler (Tucker et al. 1998).

Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Sacramento Hitch

Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta. Sacramento hitch occur in some urban streams and may tolerate highly altered habitats. Sacramento hitch face continued threats from population fragmentation (e.g., dams), agriculture (e.g., flow alteration and pollution), estuary alteration, and nonnative species. The species appears to be in long-term decline and mainly consists of scattered, small populations over a broad area. However, there is only moderate concern for overall species extinction in part due to its fairly secure establishment in some areas (Moyle et al. 2015).

Moyle et al. (2015) summarized habitat and distribution: Spawning takes place mainly in riffles of streams tributary to lakes, river, and sloughs after flows increase in response to spring rains, but spawning requirements are in need of further documentation. Moyle et al. (2015) indicate that YOY hitch spend the next two months after hatching shoaling in shallow water or staying close to aquatic plants before moving out into more open water at around 50-mm fork length.

Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Pacific Lamprey

Pacific lampreys are anadromous, rearing in freshwater before emigrating to the ocean, where they grow to full size prior to returning to their natal streams to spawn. Data from mid-water trawls in Suisun Bay and the lower Sacramento River suggest most adult Pacific lamprey migrate through the Delta in route to upstream holding and spawning grounds from late fall and winter through summer and possibly over an even broader period (Robinson and Bayer 2005; Hanni et al. 2006; Moyle et al. 2009; Clemens et al. 2012; Lampman 2011). These data also suggest that peak outmigration of Pacific lamprey through the Delta coincides with high-flow events from fall through spring (Hanni et al. 2006). Some outmigration likely occurs year-round, as observed at sites farther upstream (Hanni et al. 2006) and in other river systems (Moyle 2002).

Adults enter the Sacramento River primarily from March through June and hold in the river for about a year prior to spawning (Moyle et al. 2015). Adults have been observed at the GCID diversion from December through July and nearly all year at RBDD (Hanni et al. 2006). Spawning occurs and redds are constructed in shallow water (about 0.5 to 3.5 feet or 0.15 to 1 meter) gravel habitats in the upper river from March through July with peak spawning typically occurring in early April (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015). The eggs and pro-larvae incubate for about 1 to 1.5 months. After the larvae (ammocoetes) emerge, they drift downstream and burrow into fine sediments primarily in off-channel locations, where they rear in low flow velocity and shallow water habitats (approximately 1 foot or 0.3 meters) (Schultz et al. 2014; Moyle et al. 2015). After 3-7 years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean. Migration downstream is closely associated with rainfall events, with most migrants sampled in the upper Sacramento River being on the day of a rainfall event or within the following 2 days (Goodman et al. 2015). Data from rotary screw trapping at sites on the mainstem Sacramento River indicate that emigration of Pacific lamprey peaks from early winter through early summer, but some emigration is observed year-round at both the RBDD and the GCID diversion dam (Hanni et al. 2006).

Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Western River Lamprey

The Sacramento and San Joaquin River basins are at the southern edge of the range for Western river lamprey, here in referred to as river lamprey (Moyle et al. 2009). In the Sacramento River, they have been documented upstream to RBDD (Hanni et al. 2006; Moyle et al. 2009).

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). The adults migrate from the ocean to spawning areas during the fall and late winter (Beamish 1980). Spawning is believed to occur February through May in small tributary streams (Moyle 2002). The redds are built at the upstream end of small riffles (Moyle 2002). After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002).

Survival of river lamprey eggs and larvae is potentially dependent on river flow, and migratory habitat of the juveniles and adults. River lamprey build their spawning redds in shallow water (Moyle et al. 2015), so reductions in water level can dewater the redds. Assuming river lamprey larvae habitat requirements are similar to those of Pacific lamprey, the larvae select habitats that are often off-channel, with low flow velocity and shallow depths; therefore, they are vulnerable to stranding by reductions in water level.

Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

American Shad

American shad is a recreationally important anadromous species introduced into the Sacramento and San Joaquin River basins in the 1870s (Moyle 2002). American shad spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River.

The spawning migration may begin as early as February, but most adults migrate into the Delta in March and early April (Skinner 1962). Migrating adults generally take 2 to 3 months to pass through the Delta (Painter et al. 1979).

Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Threadfin Shad

Threadfin shad were introduced in reservoirs throughout California to provide forage for game fish, with the Sacramento and San Joaquin River basins introductions starting as early as 1959. From these transplants, they have become established in the Sacramento–San Joaquin River system and the Delta. Threadfin shad live mainly in freshwater and become progressively less abundant as salinity increases. Juveniles can form dense schools and while they are typically abundant in freshwater, they may also be found in varying salinities throughout the estuary. Threadfin shad are fast-growing but short-lived, with an average lifespan of two years. Spawning takes place in California April through August, peaking in June and July when water temperatures exceed 68°F (20°C), although spawning has been observed at 57°F to 77°F (14°C to 25°C) (Rawstron 1964; Wang 1986). The embryos hatch in three to six days and larvae immediately become planktonic.

As noted by Baxter et al. (2010), threadfin shad are widely distributed but most commonly encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Baxter et al. (2010) also noted that historic surveys by Turner (1966) found relatively high abundance in the northeast Delta in dead-end sloughs.

Threadfin shad are susceptible to entrainment in water diversions and the species is salvaged at the SWP and CVP south Delta fish salvage facilities in higher abundance than other fish species. Herbold et al. (2005) estimated annual salvage from approximately 1.5 million to about 10 million during 1994–2005. Some evidence for correlations with abundance indices has been found for water clarity, indices of predator and prey abundance, and south Delta exports (Mac Nally et al. 2010; Thomson et al. 2010).

Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Striped Bass

Striped bass is a recreationally important anadromous species introduced into the Sacramento and San Joaquin River basins between 1879 and 1882 (Moyle 2002). Despite their nonnative status and piscivorous feeding habits, they are considered recreationally and economically important because of their popularity as a major game fish in the Delta. Striped bass use the Delta as a migratory route, rearing, and seasonal foraging. The species spends the majority of its life in salt water, returning to freshwater to spawn. When not engaged in the spawning cycle, most adult striped bass in the San Francisco Estuary and Delta are found in San Pablo Bay, San Francisco Bay, and the Pacific Ocean (Moyle 2002). Adults spend about 6 to 9 months of the year in San Francisco and San Pablo Bays (Hassler 1988).

Striped bass, primarily YOY, are one of the pelagic fish of the upper estuary that have shown substantial variability in their populations, with evidence of long-term declines (Kimmerer et al. 2000; Sommer et al. 2007a). A substantial proportion of the variability in abundance index patterns has been associated with variation of outflow in the estuary (Jassby et al. 1995; Kimmerer et al. 2001; Loboschefsky et al. 2012), although this is disputed by some stakeholders (Bourez 2011). However, surveys showed that population levels for YOY striped bass began to decline sharply around 1987 and 2002 (Thomson et al. 2010), despite relatively moderate hydrology, which typically supports at least modest fish production (Sommer et al. 2007a). Moyle (2002) cites causes of decline in striped bass to include climatic factors, entrainment at project export facilities in the south Delta, other diversions, pollutants, reduced estuarine productivity, invasions by alien species, and human exploitation. Kimmerer et al. (2000, 2001) attribute the decline in juvenile YOY striped bass to declining carrying capacity, likely related to food limitation. Loboschefsky et al. (2012) showed that there had been no long-term decline for age-1 and older striped bass as of 2004.

Striped bass are distributed mainly in the lower bays and ocean during summer, and in the Delta during fall and winter. Striped bass migrate upstream to spawning grounds and spawn in spring from April to mid-June (Leet et al. 2001). Currently, it is believed that striped bass do not spawn or rear in the Sacramento River upstream of RBDD (Tehama-Colusa Canal Authority 2008). Most spawning in the Sacramento River occurs in the lower river between Colusa and the confluence of the Sacramento and Feather Rivers (Moyle 2002). About one-half to two-thirds of adults spawn in the Sacramento River and the remainder spawn in the Delta (Leet et al. 2001). After spawning, most adult striped bass move downstream into brackish and salt water for summer and fall.

Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

YOY striped bass distribute themselves in accordance with the estuarine salinity gradient (Kimmerer 2002a; Feyrer et al. 2007), indicating that salinity is a major factor affecting their habitat use and geographic distributions. Kimmerer (2002a) found that distributions of fish species, including striped bass, substantially overlapped with the low-salinity zone. Older individuals are increasingly flexible about their distribution relative to salinity (Moyle 2002). Statistically significant correlations between indices of age-0 abundance or survival in the San Francisco Estuary and Delta have been found with Delta outflow (which can be approximated by X2, the distance in km from the Golden Gate Bridge at which bottom salinity is 2 psu) (e.g., Kimmerer et al. 2009; Mac Nally et al. 2010), with evidence for greater extent of habitat as the mechanism (Kimmerer et al. 2009). However, subsequent density-dependent survival after the first summer dampens the effects of flow on subsequent recruitment (Kimmerer et al. 2000).

Historic salvage information for fish salvaged at CVP and SWP facilities is publicly available online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Black Basses

Three *Micropterus* spp. constitute the group of black basses in California, and include largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species). All three species are found in the lower American River.

Originally, it was believed that largemouth bass (*Micropterus salmoides*; previously *Micropterus salmoides salmoides*) and Florida bass (*Micropterus floridanus*; previously *Micropterus salmoides floridanus*) were sub-species of largemouth bass. Recent studies have substantiated enough variance in morphologic traits and genetic composition between the two taxa to classify them as distinct species. However, some authors and the Names of Fishes Committee (jointly hosted by the American Fisheries Society and the American Society of Ichthyologists and Herpetologists) continue to treat the Florida Bass and Largemouth Bass as subspecies (Kim et al. 2022). CDFW is among the regulating agencies that still treat the two species as a sub-species of largemouth bass (California Department of Fish and Wildlife 2024b). Therefore, for the purposes of this document, we will combine the two species for our analysis and will refer to both as largemouth bass.

Largemouth bass were introduced in California in 1891 (Moyle 2002) and have since established populations in streams and reservoirs throughout the state. They are an important invasive species in the Bay-Delta. Most largemouth bass in California are the northern species *Micropterus salmoides*, with a minority of the population being the larger *Micropterus floridanus*, which was experimentally introduced in the mid-1970s. The two species are now known to hybridize (Moyle 2002).

Largemouth bass first spawn during their second or third spring at about 7 inches in length. Spawning is limited to fresh water (Moyle 2002). The males begin building nests when the water temperature reaches about 60°F (15.6°C). Spawning takes place from April through June, at temperatures up to 75°F (23.9°C). Nests are shallow pits in depths of 3 to 7 feet and are often built next to submerged objects. Females lay their eggs in one or more nests. The eggs hatch in two to five days and sac fry usually spend five to eight days in or near the nest (Moyle 2002). For the first month or two after hatching, fry feed mainly on zooplankton. YOY bass stay close to shore in schools that swim in the open water. By the time they reach about two inches in length, the juveniles feed largely on aquatic insects and fish fry, including other largemouth bass, and after they reach four to five inches, they prey primarily on fish and crayfish. Largemouth bass are thought to be a major predator of juvenile Chinook salmon and other native fish species in the Delta (Nobriga and Feyrer 2007). In addition to the Delta, they occur in lower riverine habitats such as in the Feather River and American River. Their growth rate is highly variable, depending on genetic background, food availability, inter- and intra-specific competition, temperature regimes, and other environmental factors. Maximum size for the species is approximately 30 inches total length (TL) and the maximum age is 16 years (Moyle 2002).

Largemouth bass prefer warm, quiet waters with aquatic vegetation and low turbidity. They are known to tolerate dissolved oxygen (DO) levels as low as 1 milligram of oxygen per liter (mg/L) (Lee et al. 1980; Moyle 2002). The species thrives in areas with high levels of infestation by nonnative aquatic plants (Brown and Michniuk 2007). Recent studies suggest juvenile and larger largemouth bass abundance is positively correlated with water temperature, whereas juvenile largemouth bass abundance is greatest at intermediate levels of submerged aquatic vegetation but larger fish are widespread even in areas with limited submerged aquatic vegetation (Conrad et al. 2016). A study in the San Joaquin River between the Head of Old River (HOR) and Stockton in 2015–2016 found a mean of 333 largemouth bass per km, which were estimated to consume 3 to 5 fall-run Chinook salmon per day per km during the peak of the salmon outmigration period, compared to 0 to 24 salmon consumed per day per km by striped bass (Michel et al. 2018).

Smallmouth bass may have been first introduced in California in the 1870s (Dill and Cordone 1997). Smallmouth bass are most common in large, clear lakes and cool, clear streams with large amounts of cover. In streams they prefer complex habitat with a variety of pools, riffles, runs, rocky bottoms, and overhanging trees, while lake populations concentrate in narrow bays along shores where rocky shelves project under water.

Optimal water temperature differs with age, as adults tend to stay in areas 25°C to 27°C (77°F to 80.6°F), while younger fish prefer areas 29°C to 31°C (84.2°F to 87.8°F), reflecting their shallower water environment. Regardless of age, however, temperatures greater than 35°C (95°F) are metabolically stressful, and temperatures over 38°C (100.4°F) are lethal. Smallmouth bass are also restricted in their habitat choice by the amount of DO in the water. Although they can survive in areas with 1 to 3 mg/L, they require at least 6 mg/L for normal growth rates (University of California, Agriculture and Natural Resources 2019a). Juveniles and populations in crowded lakes may school, but this is rare and the majority are solitary hunters that stalk around some kinds of submerged debris. This localizes populations to such a degree that several reproductively independent groups can exist within a single lake. Foraging occurs throughout the day but is most intense in the evening and the early morning. Crustaceans and aquatic insects make up the majority of a smallmouth bass's diet until it reaches 3 to 5 cm (1.18–1.97 inches)

TL, at which point crayfish and fish become more important. By the time an individual reaches 10 to 15 cm (3.94–5.91 inches) TL, these larger food items dominate the diet. Smallmouth bass are opportunistic, however, and insects, amphibians, and small mammals are not uncommon sources of food (University of California, Agriculture and Natural Resources 2019a).

Smallmouth bass reach maturity in their third or fourth spring, at which point they move into shallower water. Spawning begins in May and can continue into June or July. Males construct nests 30 to 60 cm (11.81–23.62 inches) in diameter, preferably in rubble, gravel, or sand 1 meter (3 feet) deep with submerged logs, boulders, and other submerged objects acting as cover. This is only the optimal environment, however, and nests can be found on a variety of substrates varying in depth from 0.5 to 5 meters (1.64–16.4 feet). These nests may be built close together, but they are not colonial and males defend the nests against other males as vigorously as they would against predators. Spawning is initiated by a female repeatedly swimming by a nest, changing colors, and keeping her head down in a mating posture. Eventually the pair circle the nest, with the male nipping at the female and the female occasionally rubbing her abdomen on the nest floor. The pair then settle into the nest and release their eggs and milt simultaneously. Smallmouth bass are mostly monogamous, but the larger fish spawn earlier in the season and may have the opportunity to spawn again. Each female may release 2,000 to 21,000 eggs into her nest. The males guard the embryos and fan water over them to provide more oxygen. After hatching, it takes 1 to 2 weeks before fry become free swimming, and the male still guards them for another 1 to 4 weeks after that until they are too active to be herded. At 2 to 3 cm TL (0.79–1.18 inches), the young disperse to shallow water where high mortality rates are suffered because of predation and high stream flows. Those that survive generally grow to between 6 cm (2.36 inches) and 18 cm (7.09 inches) in their first year, and between 25 cm (9.84 inches) and 41 cm (16.14 inches) in their fourth, while stream populations grow at a decidedly slower rate. The largest individual on record weighed 4.1 kg (9.04 pounds) (University of California, Agriculture and Natural Resources 2019a). All life stages of smallmouth bass can occur in the freshwater regions of the Delta and lower portions of Central Valley rivers (Moyle 2002; Brown and May 2006; Brown and Michniuk 2007; Seesholtz et al. 2004).

Spotted bass are most common in moderately sized, clear, low-gradient rivers and reservoirs. In streams they spend most of their time hiding in pools, avoiding riffles or backwaters with heavy plant growth. Reservoir populations stay along steep rocky banks toward the upstream end of the reservoir. During the summer they can be found in temperatures between 24°C (75.2°F) and 31°C (87.8°F), and despite a low tolerance for brackish water, they have been found in salinities up to 10 parts per thousand (ppt). Juveniles can easily be seen schooling in shallow areas close to shore, but adults are more solitary and spend most of their time 1 meter to 4 meters (3–12 feet) deep or even farther down when temperatures equalize in winter. Like most fish, the spotted bass's diet expands as a fish gets older. Fry eat mostly zooplankton and small insects, and then move on to crustaceans and larger aquatic insects as juveniles. Individuals between 75 mm and 150 mm (2.95–5.9 inches) feed on aquatic insects, fish, crayfish, and terrestrial insects, eventually preferring crayfish (University of California, Agriculture and Natural Resources 2019b).

Maturity is reached in the second or third year and spawning occurs when temperatures reach 15°C to 18°C (59°F to 64.4°F), continuing until temperatures reach 22°C to 23°C (71.6°F to 73.4°F) in early June. Males move to shallow water in March and early April, where they construct nests 40 to 80 cm (31.5 inches) in diameter. Lake nests are built in areas 0.5 to 4.5 meters (1.64–14.76 feet) deep with large rocks and rubble or gravel, while nearly any area with low current can be used in rivers. These nests may be built close together, but spotted bass are not colonial and males defend the nests as vigorously against other males as they would against predators. Spawning is initiated by a female repeatedly swimming by a male's nest, changing colors, and keeping her head down in a mating posture. Eventually the pair circles the nest, with the male nipping at the female and the female occasionally rubbing her abdomen on the nest floor. The pair then settle into the nest and release their eggs and milt simultaneously. Spotted bass are mostly monogamous, but some males may have more than one nest. Each female lays 2,000 to 14,000 eggs per nest. The male tends to and defends the nest for up to 4 weeks until the fry disperse at 30 mm TL (1.18 inches). Growth varies with habitat. Warmwater reservoirs support the highest growth, and cold streams support the slowest. On average, however, individuals reach 65 mm to 170 mm TL (2.56–6.69 inches) in their first year and 245 to 435 mm TL (9.65–17.13 inches) in their fourth. Few live longer than 4 or 5 years, and the largest recorded individual for California was 450 mm TL (17.72 inches) (University of California, Agriculture and Natural Resources 2019b). All life stages of spotted bass can occur in the freshwater regions of the Delta.

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O.1.3.3 Shasta Reservoir

Shasta Reservoir is located directly above Shasta Dam, which is formed by waters of the Sacramento, Pit, and McCloud Rivers, as well as Squaw Creek. Lake Shasta has a storage capacity of approximately 4.5 million acre-feet. The reservoir is a popular waterbody for recreation, while also providing benefits towards flood control, power, and water supply.

Fish in Shasta Reservoir

Shasta Reservoir supports a variety of both warm-water and cold-water recreationally important fish species. Coldwater species include rainbow trout, brown trout, and land-locked Chinook salmon. Warm-water species include black basses, channel catfish, white catfish, crappie, bluegill, white sturgeon, and brown bullhead.

O.1.3.4 Aquatic Habitat

The mainstem Sacramento River provides habitat for native and introduced (nonnative) fish and other aquatic species. The diversity of aquatic habitats ranges from fast-water riffles and glides in the upper reaches to tidally influenced slow-water pools and glides in the lower reaches (Vogel 2011a).

A few miles downstream of Keswick Dam, the river enters the valley and the floodplain broadens. Historically, this area had wide expanses of riparian forests, but the riparian zone now has a great deal of urban encroachment. In the middle Sacramento River between Red Bluff and Chico Landing, the mainstem channel is flanked by broad floodplains (The Nature Conservancy 2007a). In the lower reaches downstream of Verona, much of the Sacramento River is constrained by levees. Tidal influence extends upstream to Verona with greater tidal variations occurring downstream during low river stages. Dredging, dams, levee construction, urban encroachment, and other human activities in the Sacramento River have modified aquatic habitat, altered sediment dynamics, simplified stream bank and riparian habitat, reduced floodplain connectivity, and modified hydrology (National Marine Fisheries Service 2009a). However, some complex floodplain habitats remain in the system such as reaches with setback levees and the Yolo and Sutter bypasses.

Holding Habitat

An abundance of deep, cold water pools in the mainstem Sacramento River provide habitat for holding adult anadromous salmonids during all months of the year (Vogel 2011a). Green sturgeon also use deep pools for holding and spawning, but can tolerate warmer water temperatures than salmon, so can hold farther downstream.

Spawning Habitat

Salmonid and sturgeon spawning habitat availability on the Sacramento River is affected by lack of gravel recruitment, sediment, and flow patterns as determined by the operations of the CVP and local water diverters. In general, anadromous salmonids have the most restrictive spawning habitat requirements among native species that spawn in the Sacramento River. Water temperature and other water quality parameters, depth, gravel size distribution, and flow velocity are believed to be the most important elements of anadromous salmonid spawning habitat. While the majority of splittail spawning occurs in the Yolo Bypass, the presence of submerged aquatic vegetation and floodplain habitat in the Sacramento River can be an important driver of splittail spawning outside of the Delta (Moyle et al. 2015). Gravel availability and distribution may limit spawning distribution of salmonids and sturgeon on the Sacramento River. Poytress et al. (2015) suggested that the GCID Diversion (river km 332) may represent the downstream limit of spawning for green sturgeon on the Sacramento River. This is supported by acoustic tag migration data collected by Reclamation and University of California, Davis researchers that indicated adult green sturgeon do not spend much time below this area of the Sacramento River during the spawning cycle (Poytress et al. 2015; Thomas et al. 2013). Substrate composition below the GCID Diversion consists primarily of sand. Accordingly, river km 332 may also represent the downstream limit of Chinook salmon spawning on the Sacramento River because Chinook salmon require gravel and cobbles for spawning. Additionally, the physical habitat and water quality habitat required by many native fish for spawning decreases with distance downstream and this likely limits spawning in the lower sections of the Sacramento River.

Water Temperatures

Water temperatures in the upper Sacramento River are influenced by the timing, volume, and temperature of water releases from Shasta and Keswick dams, and are currently managed according to State Water Resources Control Board (Water Board) Water Rights Orders 90-05 and 91-01, as well as the current Biological Opinions. The orders provide that Reclamation operate

Keswick and Shasta dams and the Spring Creek Power Plant to meet a daily average water temperature of 56°F as far downstream in the Sacramento River to the RBDD as practicable during periods when higher water temperatures would be harmful to winter-run Chinook salmon. Under the orders, the water temperature compliance point may be modified to an upstream location when the objective cannot be met at Red Bluff Diversion Dam. A temperature control device on Shasta Dam allows Reclamation to have more control over the temperature of the water released from the dam. Water temperature directly affects many metabolic functions of fish and affects the availability of DO, which is required for respiration. In recent years, elevated water temperatures have resulted in high estimates of mortality of winter-run eggs and alevin (Martin et al. 2017) and may have adversely affected other salmon runs and other fish species present in the Sacramento River during summer. Drought conditions make efforts to maintain suitable water temperatures in the upper Sacramento River more difficult because of reduced inflow, leading to reduced storage and a smaller cold water pool in Shasta Reservoir. Other factors influencing Shasta Reservoir's coldwater pool volume include the previous year's cold water discharges and air and water temperatures (Nickel et al. 2004).

Sediment Conditions

Shasta and Keswick dams substantially influence sediment transport in the upper Sacramento River because they block sediment that would normally be transported downstream (The Nature Conservancy 2007a; California Department of Water Resources 1985). The result has been a net loss of coarse sediment, including gravel particle sizes suitable for salmon spawning, in the Sacramento River downstream of Keswick Dam (Bureau of Reclamation 2013). To address the issue of spawning gravel loss downstream of Keswick Dam, Reclamation has placed approximately 5,000 tons of washed spawning gravel into the Sacramento River downstream of Keswick about every other year since 1997 (Bureau of Reclamation 2010a).

Substrate type is evidenced to be an important factor in spawning habitat selection for adult green sturgeon. Based on egg presence, it is thought that green sturgeon spawning occurs over several different types of substrates including sand, gravel, cobble, boulder, and bedrock (National Marine Fisheries Service 2009b; Moyle 2002). Though studies disagree on what sediment conditions are preferred for spawning, it is agreed that course sediment ranging from gravel to cobble is optimal for egg presence and larval survival (Brown 2007; Poytress et al. 2015; Wyman et al. 2018). Green sturgeon hatchling embryos are highly dependent on interstitial spaces between rocks. If they do not hatch in these spaces, their survival depends on how quickly they can find cover in interstitial spaces due to their poor swimming ability post-hatch (Kynard et al. 2005; Wyman et al. 2018). White sturgeon are evidenced to have similar substrate requirements as green sturgeon, preferring gravel and small cobbles that provide interstitial spaces for larval cover (McAdam 2011). River conditions that prevent siltation are necessary to avoid sturgeon egg suffocation and increase egg survival (Wyman et al. 2018).

Sacramento splittail predominantly spawn on submerged aquatic vegetation in flooded areas or along the edges of rising rivers (Moyle et al. 2015). Once embryos are fertilized, they adhere to the nearby vegetation and remain there as post-hatch larvae for the first few days.

Spawning Habitat Availability

The suitability of physical habitat for salmonid spawning (i.e., not including water quality parameters such as temperature and DO) is largely a function of the availability of clean, coarse gravel for constructing redds or depositing eggs, favorable depths, and suitable flow velocities. Instream flow potentially affects all three of these habitat characteristics, and therefore, often affects the availability of suitable habitat. The availability of suitable habitat as a function of flow is determined from field surveys of the fishes' spawning habitat selections (Habitat Suitability Criteria), the distribution of suitable spawning substrate, and hydraulic models that simulate site-specific effects of river flow on depth and flow velocity.

Most winter-run Chinook salmon spawn in the uppermost reach of the Sacramento River, from Keswick Dam to the confluence with Clear Creek (California Department of Fish and Wildlife Aerial Redd Survey unpublished data 2021). Operations of Shasta and Keswick dams generally determine flow in this area and therefore largely determine spawning habitat availability. However, spawning habitat availability in this reach is also affected by the seasonal ACID diversion dam, which involves placement of flashboards in the river during April and May. When the ACID dam is installed in the river, spawning habitat availability upstream of the Cow Creek confluence is lower than when the dam is removed for flows less than about 10,000 cfs, but is higher at higher flows (U.S. Fish and Wildlife Service 2003a).

Like winter-run Chinook salmon, the spawning distributions of spring-run, fall-run, and late fall-run Chinook salmon populations that spawn in the Sacramento River are primarily upstream of RBDD, with fall-run Chinook salmon spawning the farthest downstream, including about 15% of redds downstream of the RBDD, spring-run Chinook salmon spawning locations are generally between those of winter-run and fall-run Chinook salmon. Late fall-run spawning distribution is most similar to that of winter-run Chinook salmon (National Marine Fisheries Service 2017b). The spawning substrate, depth, and flow velocity requirements of the four Chinook salmon runs are generally similar, so differences in spawning habitat availability among the runs are most strongly related to differences in their spawning distributions and in the prevailing flow levels during the time of year that they spawn.

Variations in flow also have major effects on spawning habitat. Reductions in flow following spawning may result in dewatering of the redds and mortality of incubating eggs and alevins (U.S. Fish and Wildlife Service 2006). Large increases in flow may result in scouring of riverbed sediments, including any redds present, or entombment in deposited sediments.

The spawning distribution of steelhead in the upper Sacramento River is poorly known, but the suitability of spawning habitat is largely determined by the same physical habitat and water quality parameters that affect spawning suitability for Chinook salmon, although preferred depths, flow velocities, and spawning substrates are somewhat different between the two species. The availability of spawning habitat for steelhead and Chinook salmon is controlled by instream flow and the availability of suitable spawning gravel (U.S. Fish and Wildlife Service 2011c, 2011d). In the upper Sacramento River during WY 2023, 24.5 acres of rearing habitat or spawning habitat were completed, on-going, or scheduled to start in the near future. Roughly 15.5 more acres are needed to meet the 40 to 60 acre goal by 2030 (Reclamation 2024). The goal of 15,000 to 40,000 tons of gravel injected into the Sacramento River has been met each year and is anticipated to be met in WY 2024.

Green sturgeon spawn in the upper Sacramento River from the GCID Diversion near Hamilton City, California up to the Keswick Dam in Redding, California (National Marine Fisheries Service 2018a; Wyman et al. 2018). The suitability of green sturgeon spawning habitat is determined by the same physical habitat features as the above two salmonid species – depth, velocity, and substrate material – though green sturgeon preferences in each differ from the salmonids. Like the above species, flow controls the distribution of suitable spawning habitat. Higher flows may disqualify previously used spawning habitat by increasing the depth and velocity of pools so that they exceed the preferences of potential spawners. On the other hand, increased flows could open up areas of suitable habitat that were previously too shallow. Green sturgeon appear to select microhabitats within the suitable spawning habitat. Variations in flow that lead to changes in the physical features of the selected spawning microhabitat during the egg incubation or larval emergence period could affect the fitness benefits associated with the chosen habitat, which are likely important for reproductive success (Wyman et al. 2018). There may be suitable habitat above Cow Creek for green sturgeon but with cold water releases from Keswick Dam and the ACID diversion dam migration barrier, none have been confirmed (National Marine Fisheries Service 2018a; Poytress et al. 2015).

White sturgeon spawning distribution likely occurs from Colusa to Verona in the Sacramento River with occasional spawning events in the Yolo Bypass (Heublein et al. 2017a). Spawning habitat suitability is largely determined by the same physical habitat parameters that affect spawning suitability for Chinook salmon and green sturgeon. White sturgeon spawning timing and distribution separates their suitable spawning habitat from that of green sturgeon. Both sturgeon species have similar physical habitat preferences, though white sturgeon prefer slightly higher velocities. White sturgeon larvae are also dependent on interstitial spaces to hide. The availability of spawning habitat with suitable depths, gravel or cobble substrate, and complex flow regimes are necessary for white sturgeon reproductive success (Heublein et al. 2017a; Wyman et al. 2018).

Sacramento splittail depend on brackish rearing habitat in the San Francisco Estuary and floodplain and river-edge spawning habitat above the estuary in the lower Sacramento River. Floodplains and areas of flooded vegetation are critical for Sacramento splittail spawning and rearing areas. Sommer et al. (2008) reported early life stages were strongly associated with shallow areas and submerged vegetation. A high abundance of invertebrates in inundated floodplains may serve as prey to increase growth rates for rearing splittail (Feyrer et al. 2007).

Rearing Habitat

Rearing habitat suitability for juvenile (including fry) salmonids is generally related to flow much as described above for spawning habitat suitability with the exception that the physical habitat characteristics important for rearing also include cover and the Habitat Suitability Criteria for depth and flow velocity are slightly different (U.S. Fish and Wildlife Service 2005).

Inundated floodplains typically provide large areas of suitable rearing habitat for juvenile salmonids (Sommer 2001a). In the Sacramento River between Red Bluff and Chico Landing, the mainstem channel is flanked by broad floodplains. Ongoing sediment deposition in these areas provides evidence of continued inundation of floodplains in this reach (California Department of Water Resources 1994). Between Chico Landing and Colusa, the Sacramento River is bounded by levees that provide flood protection for cities and agricultural areas. However, the levees in

this portion of the Sacramento River are, for the most part, set back from the mainstem channel such that flooding can be significant within the river corridor (The Nature Conservancy 2007b). Off-channel floodplain habitat is critical for Central Valley Chinook salmon. This habitat provides food resources (Sommer et al. 2001a), increased rearing habitat (Cordell et al. 2011), and the duration of flooding positively affects fish body condition (Takata et al. 2017).

Vogel (2011a) suggested that the mainstem Sacramento River may not provide adequate rearing areas for fry-stage anadromous salmonids, as evidenced by rapid displacement of fry from upstream to downstream areas and into non-natal tributaries during increased flow events. Underwater observations of salmon fry in the mainstem Sacramento River suggest that optimal habitats for rearing may be limited at higher flows (Vogel 2011a).

Green sturgeon rearing habitat in the Sacramento River is not well documented, and it is unknown how long juveniles spend rearing in the Sacramento River before migrating downstream to the Bay-Delta (National Marine Fisheries Service 2018a). There has historically been an absence of juveniles measuring less than 200 mm in the Delta suggesting that juveniles rear in the upper Sacramento River for some months before beginning their migration down river (California Department of Fish and Game 2002a; Heublein et al. 2017a). Rearing habitat is essential for the recovery and persistence of green sturgeon (National Marine Fisheries Service 2018a).

There is little known about white sturgeon rearing habitat in the Sacramento River. There is evidence of a primary dispersal from spawning grounds during the larval life stage, and a secondary downstream dispersal during the juvenile life stage, inferring that the fish are spending time rearing between the two dispersals (Heublein et al. 2017a). The availability of suitable rearing habitat relies on water temperatures within the suitable range and flows. Suitable larval rearing habitat is thought to be characterized by inundated channel margins and off-channel areas. Threats to high quality rearing habitat such as channel modification or food contamination could have detrimental effects on juvenile growth and survival (Heublein et al. 2017b).

O.1.3.5 Fish Passage and Entrainment

Historically, anadromous salmonids had access to a minimum of approximately 493 miles of habitat in the Sacramento River (Yoshiyama et al. 1996). After completion of Shasta Dam in 1945, access to approximately 207 miles was blocked. Keswick Dam, just downstream of Shasta Dam, is now the upstream extent of available habitat for anadromous fish in the Sacramento River.

Historically, three large-scale, upper Sacramento River diversions, the ACID and GCID intakes and RBDD, were of particular concern as potential passage or entrainment problems for Chinook salmon, steelhead, sturgeon, and other migratory fish species (National Research Council 2012; National Marine Fisheries Service 2009a; McEwan and Jackson 1996). However, somewhat recent changes to these facilities have improved fish passage. The RBDD was decommissioned in 2013 and its gates permanently locked in the up position since 2011. Fish screen installation was essentially completed at GCID in 2001 and new fish ladders, and fish screens were installed at ACID and began operating in 2001 (National Research Council 2012).

Numerous other diversions are located on the Sacramento River. Herren and Kawasaki (2001) documented up to 431 diversions from the Sacramento River between Shasta Dam and the city of Sacramento. Other major diversions that are now screened include, but are not limited to, Reclamation District No. 108 (RD 108), Reclamation District 2035/ Woodland Davis Clean Water Agency, Sutter Mutual Water Company's diversions (SMWC), and Red Bluff Diversion Dam (RBDD) (NCWA 2021). In the lower Sacramento River, the exact number of agricultural diversions along the Sacramento River between Verona and the I Street Bridge is unknown but they are believed to be numerous and of various types, capacities, and timing of use. Most are unscreened. The two largest diversions to the Natomas Basin operated by the Natomas Central Mutual Water Company (Sankey and Pritchard Lake) have been screened in recent years to reduce juvenile salmonid entrainment. A third diversion to the Natomas Basin (Elkhorn) is not yet screened but plans for screening this facility are pending (Davis pers. comm. 2019). Currently there are no fish passage issues in the Sacramento River reach from Verona to the I Street Bridge. Other fish passage barriers on the Sacramento River include the Sacramento River Deep Water Ship Channel locks, Fremont Weir (Yolo Bypass), Sutter Bypass, and the Delta Cross-Channel (DCC) gates (70 FR 17386). A set of locks at the upstream end of the Sacramento River Deep Water Ship Channel, where it connects to the Sacramento River, blocks the migration of all fish from the deep-water ship channel back to the Sacramento River (California Department of Water Resources 2005a).

Hanson (2001) studied juvenile Chinook salmon entrainment at unscreened diversions at the Princeton Pumping Plant and documented the entrainment of approximately 0.05% of juvenile Chinook salmon passing the diversion. Similar to the results of Hanson (2001), Vogel (2013) found that entrainment of juvenile salmon in 12 unscreened diversions was low relative to other fish species. Mussen et al. (2014) examined the risk to green sturgeon from unscreened water diversions and found that juvenile green sturgeon entrainment susceptibility (in a laboratory setting) was high relative to that estimated for Chinook salmon, suggesting that unscreened diversions could be a contributing mortality source for threatened Southern DPS green sturgeon. Reclamation is currently coordinating with the USFWS to support improvements at other fish screens.

O.1.3.6 Harvest

Harvest for the Sacramento River fall-run Chinook salmon consists of combination of in-river and ocean fisheries. The Pacific Fishery Management Council (PFMC) uses regional closures and minimum size limits to avoid impacts to winter-run Chinook salmon. In 2022, the total harvest of Sacramento fall-run Chinook salmon was estimated at 184,500 for ocean fisheries and 4,900 for in-river fisheries (Table O-4). Due to poor survival and the current status of Sacramento fall-run stock, the 2023 commercial and recreational salmon fisheries were closed. Harvest of Sacramento fall-run is expected to be low in 2023, and bycatch estimates will not be available until 2024.

Table O-4. Harvest and Abundance Indices for Adult Fall-run Chinook Salmon

Year	Ocean Harvest South of Cape Falcon [a]				River Harvest [d]	Spawning Escapement			
	Troll	Sport	Non-Ret [b]	Total		Natural	Hatchery	Total	Sacramento Index [c]
1983	246,600	86,300	-	332,900	18,000	91,700	18,600	110,200	461,100
1984	266,200	87,000	-	353,100	25,900	120,200	38,700	159,000	538,100
1985	355,500	158,900	-	514,400	39,100	210,100	29,300	239,300	792,800
1986	619,000	137,500	-	756,400	39,200	218,300	21,800	240,100	1,035,700
1987	686,100	173,100	-	859,200	31,800	175,200	19,800	195,100	1,086,100
1988	1,163,200	188,300	-	1,351,500	37,100	200,700	26,800	227,500	1,616,100
1989	602,800	157,100	-	759,900	24,900	127,600	24,900	152,600	937,300
1990	507,300	150,400	-	657,800	17,200	83,300	21,700	105,100	780,000
1991	300,100	89,600	-	389,700	26,000	92,800	26,000	118,900	534,600
1992	233,300	69,400	-	302,800	13,300	59,900	21,700	81,500	397,600
1993	342,800	115,300	-	458,100	27,700	112,800	24,600	137,400	623,200
1994	303,500	168,800	-	472,300	28,900	135,000	30,600	165,600	666,700
1995	730,700	390,400	-	1,121,000	48,200	253,800	41,500	295,300	1,464,600
1996	426,800	157,000	-	583,800	49,200	269,100	32,500	301,600	934,700
1997	579,700	210,300	-	790,000	56,300	281,600	63,300	344,800	1,191,100
1998	292,300	114,000	-	406,300	69,800	176,000	69,900	245,900	722,100
1999	289,100	76,200	-	365,300	68,900	357,600	42,200	399,800	834,000
2000	421,800	152,800	-	574,600	59,500	370,000	47,600	417,500	1,051,600
2001	284,400	93,400	-	377,900	97,400	539,400	57,400	596,800	1,072,000
2002	447,700	184,000	-	631,700	89,200	684,200	85,600	769,900	1,490,800
2003	501,600	106,400	-	608,000	85,400	414,600	108,400	523,000	1,216,300
2004	621,800	212,600	-	834,500	46,800	206,200	80,700	286,900	1,168,200
2005	367,900	127,000	-	494,900	64,600	214,900	181,100	396,000	955,500
2006	149,900	107,700	-	257,700	44,900	196,500	78,500	275,000	577,600

Year	Ocean Harvest South of Cape Falcon [a]				River Harvest [d]	Spawning Escapement			
	Troll	Sport	Non-Ret [b]	Total		Natural	Hatchery	Total	Sacramento Index [c]
2007	119,900	32,000	-	152,000	14,300	70,100	21,300	91,400	257,700
2008	3,200	900	-	4,100	100	47,300	18,000	65,400	69,600
2009	-	200	100	300	-	24,900	15,900	40,900	41,100
2010	11,200	11,400	300	22,800	2,700	91,100	33,200	124,300	149,800
2011	46,700	22,800	-	69,500	18,200	77,900	41,500	119,300	207,000
2012	183,100	93,400	300	276,700	65,800	166,200	119,200	285,400	627,900
2013	290,700	114,300	-	404,900	57,500	305,600	101,200	406,800	869,300
2014	240,600	62,400	-	303,000	35,700	168,700	43,800	212,500	551,200
2015	100,100	24,500	-	124,600	16,900	74,500	39,000	113,500	254,900
2016	62,900	28,900	-	91,800	23,900	56,300	33,400	89,700	205,300
2017	38,700	31,900	-	70,700	22,100	17,900	26,500	44,300	137,100
2018	53,700	45,000	-	98,600	16,300	71,700	33,800	105,500	220,400
2019	248,600	74,400	-	323,000	20,300	121,600	42,100	163,800	507,100
2020	154,900	44,600	-	199,500	14,900	100,200	37,900	138,100	352,500
2021	165,800	41,700	-	207,400	10,800	72,800	32,800	104,500	322,700
2022 [e]	134,900	49,500	-	184,500	4,900	32,700	29,100	61,900	251,200

Source: Pacific Fishery Management Council 2023a.

[a] Ocean harvest for the period September 1 through August 31.

[b] Mortalities estimated from non-retention ocean fisheries (e.g., coho-only fisheries, non-retention GSI sampling). In 2008, there were 37 estimated mortalities as a result of non-retention fisheries that have been rounded to 0 in this table.

[c] The Sacramento Index is the sum of (1) SRFC ocean fishery harvest south of Cape Falcon between September 1 and August 31, (2) SRFC impacts from non-retention ocean fisheries when they occur, (3) the recreational harvest of SRFC in the Sacramento River Basin, and (4) the SRFC spawner escapement.

[d] Estimates derived from CDFW Sacramento River Basin angler survey. Estimates not marked with a footnote are inferred from escapement data and the mean river harvest rate estimate.

[e] Preliminary estimates.

California Central Valley steelhead catch from angler report cards between 2015–2019 had a mean value of 3,184 for wild origin and 917 for hatchery fish in the Sacramento River & Tributaries location code (California Department of Fish and Wildlife 2021).

O.1.3.7 Hatcheries

The Livingston Stone National Fish Hatchery (LSNFH), located at the foot of Shasta Dam, is a conservation hatchery that has been producing and releasing juvenile winter-run Chinook salmon since 1998. There is growing concern about potential genetic effects that may result from the use of a conventional hatchery program to supplement naturally reproduced, wild winter-run Chinook salmon populations. The latest performance standards at LSNFH are designed to maintain stock integrity and conserve both genetic and life history diversity (U.S. Fish and Wildlife Service 2016). When possible, the hatchery uses natural origin broodstock with a wide range of phenotypic characteristics, including run timing and age.

Recent research has indicated that adult Chinook salmon are susceptible to thiamine deficiency from an unbalanced diet in the ocean that is dominated by anchovies, and the deficiency may subsequently reduce survival in their offspring. Researchers from UC Davis partnering with the LSNFH conducted a study from December 2019–June 2020 and found a mean mortality of less than 1% in winter-run fry from maternal treatment injections of thiamine, compared to 33% mortality in untreated maternal broodstock (Bell 2022). Further research to determine the effects of thiamine treatments on improving the winter-run Chinook salmon population are currently underway, as 93% of adults arriving to the LSNFH in 2022 showed signs of deficiency (Meyers et al. 2023).

Annual hatchery releases into the Sacramento River from LSNFH have varied in recent years to assist in rebuilding and recovery of the winter-run population. In BY2020, 310,953 were released into the Sacramento River and in BY2022, 741,000 juveniles were released (Meyers et al. 2021; 2022; 2023). Historically, the estimated natural origin production that passed RBDD was estimated around 5.2 million juveniles per year, based on the 2002–2009 average (see Table 6 in Poytress and Carrillo 2011). Natural origin production since then has decreased to an estimated 2.2 million juvenile winter-run in BY2020 and 311,058 juveniles in BY2022.

The LSNFH minimizes hatchery effects in the population by preferentially collecting wild adult winter-run Chinook salmon for brood stock (U.S. Fish and Wildlife Service 2011b). Up to 15% of the estimated run size for winter-run Chinook salmon may be collected for brood stock use (up to a maximum of 120 natural-origin winter-run Chinook salmon per brood year). Although there is no adult production goal, LSNFH releases up to 250,000 winter-run Chinook salmon a year in late January or early February. Winter-run Chinook salmon are released at the pre-smolt stage and are intended to rear in the freshwater environment prior to smoltification. The pre-smolts are released into the Sacramento River at Caldwell Park in Redding, about 10 miles downstream of the hatchery. All juvenile winter-run Chinook salmon produced at LSNFH are adipose fin-clipped and coded wire-tagged (California Hatchery Scientific Review Group 2012). In an effort to jump start the population, 139,000 – 237,148 juvenile winter-run from LSNFH were released into Battle Creek starting in 2018 (Sisco 2019 and Meyers et al. 2021; 2022; 2023).

The Feather River Fish Hatchery (FRFH) was constructed in the 1960s and began operations in 1967 to mitigate for the loss of upstream spawning and rearing habitat as a result of the Oroville Dam. The Oroville Dam and reservoir are features of the SWP. Located downstream of the Oroville Dam, the FRFH conducts two artificial propagation programs for Central Valley Chinook salmon (spring-run and fall-run) and one artificial propagation program for Central Valley Steelhead (California Department of Fish and Wildlife 2023f).

Flows in the Sacramento River are monitored as a metric associated with the release criteria of hatchery raised salmon. Flows in the Sacramento River below 12,000 cubic feet per second upstream of the Delta Cross Channel Junctions can lead to significantly reduced survival of juvenile salmon because of reduced travel times, exposure to increased predation and increased risk of diversion into the interior Delta (Perry et al. 2015, NMFS 2019). A total of 2,338,945 Central Valley Chinook salmon (117% of the production goal) were 100% Coded-Wire Tagged (CWT) and marked with an adipose fin-clip and released into the lower Feather River at Boyd's Pump Boat Launch (River Mile (RM) 22.3) and Gridley Boat Launch (RM 50) during March and April of 2023. The hatchery had a 2023 production goal of 2 Million (+/- 10%) Central Valley spring-run Chinook smolts (California Department of Fish and Wildlife 2023g). A total of 408,985 brood year 2022 California Central Valley steelhead were released into the Feather River in February 2023.

O.1.3.8 Disease

Several endemic salmonid-specific pathogens occur in the Sacramento River: *Ceratonova shasta* (salmonid ceratomyxosis), *Parvicapsula minibicornis*, *Flavobacterium columnare* (columnaris), Infectious Hematopoietic Necrosis virus, *Renibacterium salmoninarum* (bacterial kidney disease), *Flavobacterium psychrophilum* (cold water disease), Ichthyophthirius multifiliis (white spot disease or Ich), and *Aeromonas salmonicida* (Furunculosis) (California Department of Water Resources 2004; Foott 2014). Of these, *Ceratonova shasta* is of most concern for fisheries management in the Sacramento River watershed (Foott 2014; Foott et al. 2017). Most fish hatcheries employ best management practices and protocols to minimize the spread of diseases (Cramer Fish Sciences 2016).

Ceratonova shasta (salmonid ceratomyxosis) is endemic to the Sacramento River Basin. While native fish have developed some resistance to the disease, mortality in all ages of anadromous and resident salmonids still occurs. Steelhead appear to be particularly susceptible to the disease, compared to Chinook salmon (California Department of Water Resources 2004). Fish can become infected at temperatures as low as 39°F; however, mortality predominantly occurs at water temperatures exceeding 50°F (Bartholomew 2012).

The risk of infection in the Sacramento River Basin to *Ceratonova shasta* is highest when the fish remain for an extended period in an infectious zone, an area with a high concentration of infectious pathogen(s) (Foott et al. 2017; Pacific Fishery Management Council 2018). An infectious zone may develop when the following factors coincide: low flow velocity and volume (especially in proximity to spawning areas) and water temperatures above 54°F–59°F (Ray and Bartholomew 2013; Foott et al. 2017; Pacific Fishery Management Council 2019). Therefore, risk of infection increases when river flow decreases and water temperature increases.

O.1.3.9 Predation

In the Sacramento River, predation on native species can be high, particularly for juvenile Chinook salmon, due to climate change, a complex water diversion system, hatchery domestication effects, lack of juvenile rearing habitat, and non-native predatory fish species (Brown and Moyle 1981; National Marine Fisheries Service 2018b; Stompe et al. 2020). Factors such as climate change and habitat loss have served to limit the natural production potential of Chinook salmon in the Sacramento River, while domestication of hatchery-reared fish and watershed engineering increase the vulnerability of juvenile Chinook salmon to predation by both native and non-native predators (National Marine Fisheries Service 2018b). High rates of predation have been known to occur at diversion facilities and areas where rock revetment has replaced natural riverbank vegetation (National Marine Fisheries Service 2009a). Chinook salmon fry, juveniles, and smolts are more susceptible to predation at these locations because predatory fish, including Sacramento pikeminnow and striped bass, congregate in these areas because they provide better predator refuge (Williams 2006; Tucker et al. 2003).

Predation on larval and small juvenile green and white sturgeon is not well documented in the Sacramento River, though it is known that various native species prey on small sturgeon, including prickly sculpin, largemouth bass, and striped bass (Heublein et al. 2017b; Baird et al. 2019; Gruber et al. 2022). Predation is a common cause of mortality for larval fish species, and can increase based on environmental conditions. Lower turbidity, higher light levels, and lack of cover have been linked to higher white sturgeon predation rates in laboratory studies. Sturgeon become less vulnerable to predation as they grow larger (Gadomski and Parsley 2005; Gruber et al. 2022). Additionally, sturgeon do not seem to be the preferred prey choice if there are alternative prey sources once they are over 150 mm TL (Baird et al. 2019).

Predation by nonnative and introduced fish species in the Sacramento River has become a major concern in recent years. Unfortunately, quantifying the impact nonnative predators have on native prey population dynamics is challenging given the many variables affecting their survival. Primary nonnative fish predators within the Sacramento River are the Striped *Morone saxatilis* and Largemouth Bass *Micropterus salmoides* and other sunfishes (Centrarchidae), White *Ameiurus catus* and Channel Catfish *Ictalurus punctatus* (Michel et al. 2018; Brandl et al. 2021). Despite the fact that these predators predate the dramatic declines documented in many of the listed species, they also predate fisheries monitoring, leading to knowledge gaps about their initial and cumulative impacts on native fish (Nobriga and Smith 2020). However, restoring riparian vegetation, increasing flows, the sinuosity, and heterogeneity of rivers, and removing predator hotspots are all hypothesized to benefit native species survival and reduce nonnative predator abundance (Lawrence et al. 2014; Hellmair et al. 2018; Notch et al. 2020; David et al. 2023). Management strategies that improve these environmental variables may contribute to improving the survival of all listed species in the Sacramento River and reduce nonnative predator habitat and predation risks.

O.1.4 Battle Creek

Battle Creek is a tributary that enters the Sacramento River about 20 miles southeast of Redding. The cold, spring-fed waters of Battle Creek historically supported large runs of Chinook salmon and steelhead. Diversion dams constructed in the early 1900s for hydroelectric power production reduced instream flow and blocked anadromous salmonids from accessing habitat in large portions of the north and south forks of Battle Creek.

O.1.4.1 Coleman National Fish Hatchery

Coleman National Fish Hatchery, located on Battle Creek, was established in 1942 by Reclamation to partially mitigate habitat and fish losses from historical spawning areas caused by construction of Shasta and Keswick dams. The hatchery is funded by Reclamation and operated by the USFWS. The hatchery steelhead program was initiated in 1947 to mitigate losses resulting from the CVP (U.S. Fish and Wildlife Service 2012). The weir at the hatchery is a barrier to anadromous fish passage, as are various Pacific Gas and Electric Company (PG&E) dams (e.g., Wildcat) located on Battle Creek (Yoshiyama et al. 1996). Yoshiyama et al. (1996) reported that the Coleman South Fork Diversion Dam is the first impassible barrier on Battle Creek.

O.1.4.2 Restoration

Planning to restore naturally spawning anadromous fish populations in Battle Creek was initiated in 1995, and construction began in 2010 on the Battle Creek salmon and steelhead Restoration Project (Bureau of Reclamation 2014a). When complete, the restoration project will restore ecological processes along 42 miles of Battle Creek and six miles of tributaries while minimizing reductions to hydroelectric power generation. To date, five dams have been decommissioned on Battle Creek (Wildcat, Coleman, South, Lower Ripley, and Soap Creek Feeder diversion dams). New fish screens and fish ladders that meet NMFS and CDFW criteria have been constructed at three diversion dams (North Battle Creek Feeder, Eagle Canyon, and Inskip Diversion Dams). Connectors are proposed that prevent the discharge of North Fork Battle Creek water to South Fork Battle Creek and the mixing of flow sources. Higher minimum flow requirements (MFR) will increase instream flows, subsequently cooling water temperatures, increasing stream area, and providing reliable passage conditions for adult salmonids in downstream reaches. The project will result in 42 miles of newly accessible anadromous fish habitat and improved water quality for the Coleman National Fish Hatchery. As noted above, 200,000 juvenile winter-run Chinook salmon from LSNFH were released into Battle Creek in 2018. Since 2018, 567,412 juvenile winter-run Chinook salmon have been released into Battle Creek to initiate reintroduction efforts (National Marine Fisheries Service 2021a). In 2020, the first year adults were allowed to migrate upstream, over 1,000 adults from these releases returned and were the first winter-run Chinook salmon to successfully spawn in Battle Creek in over 100 years.

Additionally, Reclamation proposed, as part of the implementation of the long-term operations of the CVP and SWP, to fund reintroduction efforts for winter-run Chinook salmon on Battle Creek for ten years (Bureau of Reclamation 2019). This funding will address and complement ongoing efforts of the Battle Creek salmon and steelhead Restoration Project. The Battle Creek Restoration Project is a collaborative effort among several federal and state agencies and Pacific Gas and Electric Company. The partnership provides a framework for expanding winter-run Chinook salmon spawning to cold water habitat not in the Sacramento River.

O.1.5 Clear Creek

The action area includes all reaches of Clear Creek that are accessible to anadromous fish from its confluence with the Sacramento River to Whiskeytown Dam. Beginning in 1995, the CVPIA and later the CALFED Bay-Delta Program have conducted salmonid habitat and flow restoration in Clear Creek and re-established runs of Central Valley spring-run Chinook salmon and California Central Valley steelhead. The Clear Creek Technical Team was established in 1996 to facilitate implementation of these CVPIA and CALFED Bay-Delta Program restoration actions.

In 2009, NOAA's NMFS issued a Coordinated Long-Term Operations Biological Opinion. Under this biological opinion, Reasonable and Prudent Alternative (RPA) actions included flow and temperature management on Clear Creek. The 2019 NMFS Coordinated Long-Term Operations Biological Opinion updated and enhanced these commitments by updating flow schedules including pulse flows and channel mobilization flows, prescribing higher base flows during critical time periods in all but critical water years, and reaffirming the water temperature targets prescribed in the 2009 Biological Opinion RPAs (National Marine Fisheries Service 2019).

Since its establishment, the Clear Creek Restoration Program (CCRP) identified and implemented a variety of actions to improve salmon and steelhead habitat and the ecosystem on which these species depend. Past and continued actions include increased minimum flows, summer water temperature control through flow management, removal of a low-head dam, large-scale stream and floodplain restoration, gravel augmentation, spring and early summer pulse flows, and erosion control (Clear Creek Technical Team 2018).

Priority restoration actions for Clear Creek from NMFS's Biological Opinion: Lower Clear Creek Anadromous Fish Habitat Restoration and Management Project (National Marine Fisheries Service 2014a) include the following:

- Develop a new spawning gravel budget and implement a long-term gravel augmentation plan in Clear Creek, including acquisition of a long-term gravel supply.
- Operate the Clear Creek segregation weir to create reproductive isolation between fall-run Chinook salmon and spring-run Chinook salmon.
- Manage releases from Whiskeytown Dam with instream flow schedules and criteria to provide suitable water temperatures for all life stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat quality and availability.
- Develop water temperature models to improve Clear Creek water temperature management.
- Adaptively manage Whiskeytown Reservoir releases and water temperatures to evaluate whether anadromy can be increased without causing adverse impacts on other species.
- Implement channel maintenance flows in Clear Creek called for in the CVP/SWP biological opinion.

O.1.5.1 Water Operations Management

Trans-basin diversion of water from the Trinity Basin to Clear Creek and the Sacramento Basin occurs via the Clear Creek Tunnel. Water released from Whiskeytown Reservoir to Clear Creek, or conveyed to Spring Creek Power Plant via the Spring Creek Tunnel and discharged into Keswick Reservoir and the Sacramento River, is managed for hydropower generation, water quality maintenance, flood control, and to support water supply and temperature objectives in Clear Creek and the Sacramento system.

The 2000 Trinity River Mainstem Fishery Restoration Record of Decision (U.S. Department of Interior 2000) limits trans-basin diversions from Lewiston Reservoir to Whiskeytown Reservoir, which can affect Reclamation's water temperature operations and CVP deliveries in Clear Creek and the Sacramento River. Annual water diversions from the Trinity Division to the Shasta Division via the Clear Creek Tunnel and Whiskeytown Lake have averaged 604,400 acre-feet per year from 2001–2022 (Trinity River Restoration Program 2023a).

Whiskeytown Dam has two outlets that access different water temperature zones in the stratified reservoir. Reclamation evaluates thermal profiles of Whiskeytown Reservoir throughout the year and operates the outlets to help manage downstream water temperatures in Clear Creek and conserve the coldwater pool (National Marine Fisheries Service 2019).

Flow

Whiskeytown Reservoir operations include releases to Clear Creek for water temperature management, minimum instream base flows, and spring attraction and channel maintenance flows (National Marine Fisheries Service 2019). Pursuant to the 2019 Biological Opinion, Reclamation manages flows in Clear Creek in all water year types except critically dry ("Critical") years to provide base flows for the Central Valley spring-run Chinook salmon and California Central Valley steelhead egg-to-fry life stage of at least 200 cfs from October 1 to May 31 and at least 150 cfs from June 1 to September 30. In Critical water years, flows in Clear Creek may be reduced below these levels based on available water from Trinity Reservoir.

Reclamation coordinates Clear Creek flow release schedules with the NMFS, USFWS, and CDFW to minimize the adverse effects of CVP-controlled water operations on all life stages of federally listed anadromous fish species in Clear Creek.

Water Temperature

Attainment of water temperature objectives for Central Valley spring-run Chinook salmon and California Central Valley steelhead in Clear Creek is among the key management objectives for operation of Whiskeytown Dam. Pursuant to the NMFS Coordinated Long-Term Operations Biological Opinion (National Marine Fisheries Service 2019), Reclamation manages water temperatures in Clear Creek to meet daily average water temperature objectives of 60°F or less from June 1 through September 14 for adult CV spring-run Chinook salmon and juvenile California Central Valley steelhead and 56°F or less from September 15 through October 31 for Central Valley spring-run Chinook salmon eggs and fry.

Two temperature curtains in Whiskeytown Reservoir are used to pass cold water through the bottom layer of the reservoir and limit warming from Carr Power Plant to Clear Creek or Spring Creek Power Plant. Reasonable and Prudent Measure 2 of the 2019 Biological Opinion specifies actions to minimize adverse impacts to listed species during operations in Trinity Division/Clear Creek at Whiskeytown Dam. These actions include continued maintenance of the temperature control curtains in Whiskeytown Reservoir, consideration of real-time species information when making decisions regarding operational adjustments, and coordination with NMFS in Critical water years on the timing, frequency, duration and magnitude of flows below 150 cfs (National Marine Fisheries Service 2019).

O.1.5.2 Clear Creek below Whiskeytown Reservoir

Clear Creek continues for 18.1 miles downstream of Whiskeytown Lake into the Sacramento River downstream of the CVP Keswick Dam and south of the City of Redding.

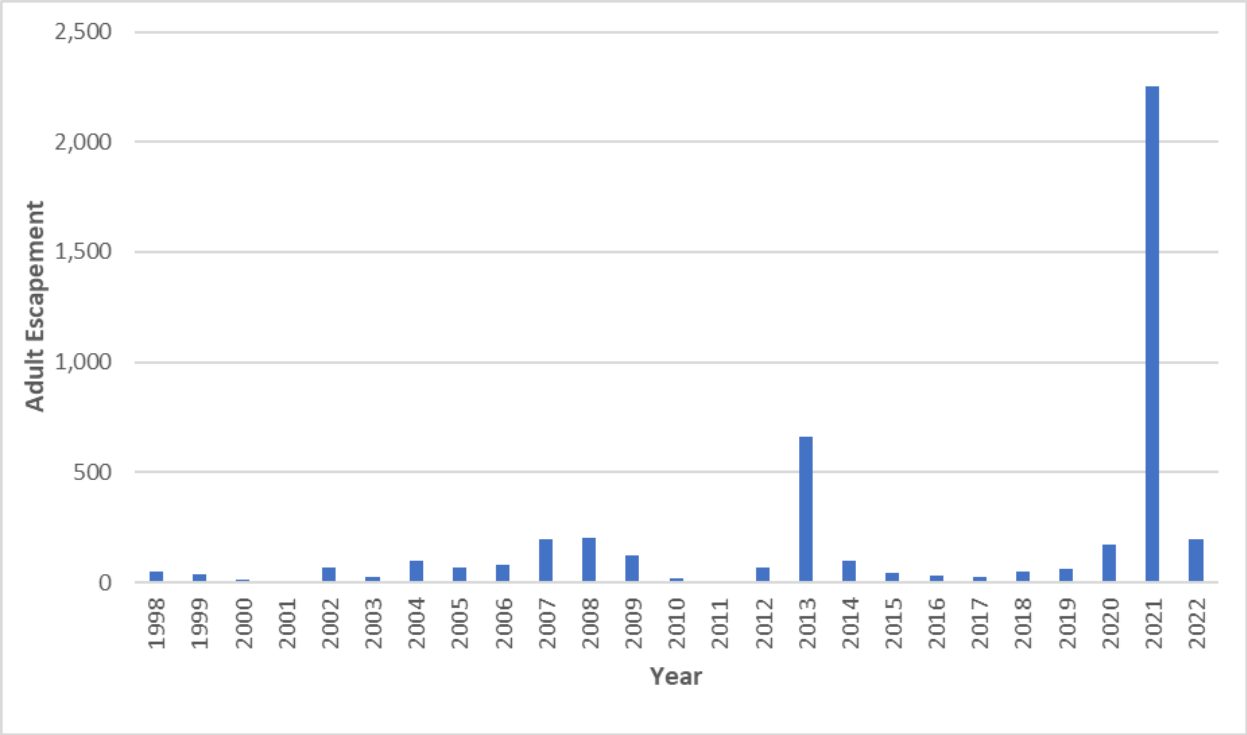
Fish Evaluated in Clear Creek

The analysis is focused on the following species:

- Spring-run Chinook salmon, Central Valley ESU
- Fall- and late fall-run Chinook salmon, Central Valley ESU
- Steelhead, California Central Valley DPS
- Pacific lamprey
- Hardhead

Spring-run Chinook Salmon, Central Valley ESU

Central Valley spring-run Chinook salmon have re-established in Clear Creek following implementation of the CCRP. From 1998 to 2021, adult escapement ranged from 0 in 2001 to 2,252 in 2021 and averaged 184 (Figure O-1; Azat 2023).



Source: Azat 2023.

Figure O-1. Spring-run Chinook Salmon Clear Creek Returns, 1998–2022

The removal of the McCormick-Saeltzer Dam in 2000 opened nearly 12 miles of access to areas just downstream of Whiskeytown Dam for a total of 18 miles of Central Valley spring-run Chinook salmon (as well as Central Valley steelhead) habitat. Adult Central Valley spring-run Chinook salmon migrate upstream into lower Clear Creek beginning in early June and spawn in the uppermost reaches from September through early to mid-October. Since 2003, the USFWS has installed a temporary picket weir from late August through early November to allow spawning spring-run Chinook salmon to be spatially separated from fall-run Chinook salmon, which have an overlap in spawning timing (National Marine Fisheries Service 2014c). Spatial overlap during spawning could result in egg and embryo mortality due to redd superimposition or hybridization and genetic introgression between spring and fall runs (National Marine Fisheries Service 2014c).

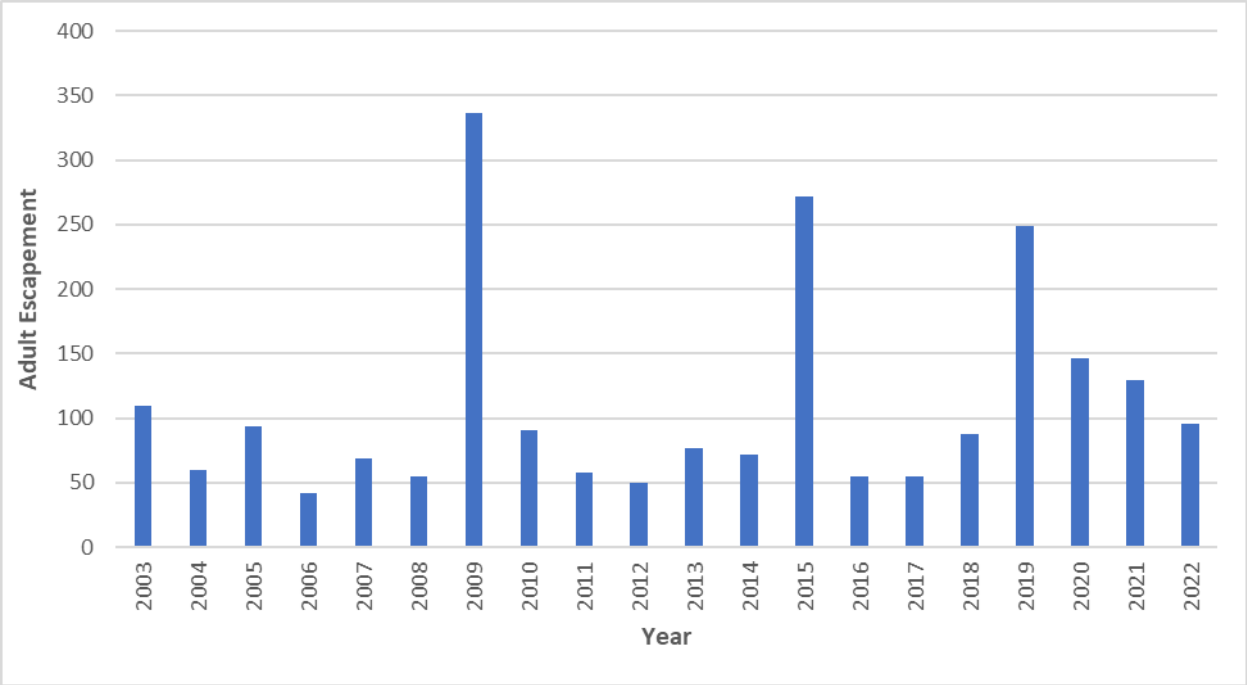
Water temperature criteria (maximum mean daily 56°F) in Clear Creek are set to be protective of spring-run Chinook salmon during spawning and incubation (September 15 to October 31). In warm years with low to no precipitation in fall months, these targets have occasionally not been met due to lack of adequate coldwater pool in Whiskeytown Reservoir. One such year was 2018, but temperature criteria were met for all but four days during the spawning period (Clear Creek Technical Team 2018).

Rotary screw trap data on spring-run Chinook salmon outmigration from Clear Creek show spring-run Chinook salmon juveniles emigrating during late October through late May (Schraml and Chamberlain 2019a; Chamberlain 2019b; Schraml et al. 2020). Peak emigration of spring-run Chinook salmon juveniles occurs in November, with fewer fish exiting each week through the end of May (Figure O-1). The majority of the outmigrating juveniles are fry, generally under 40 mm fork length (Schraml et al. 2018).

Fall-/Late Fall-run Chinook Salmon, Central Valley ESU

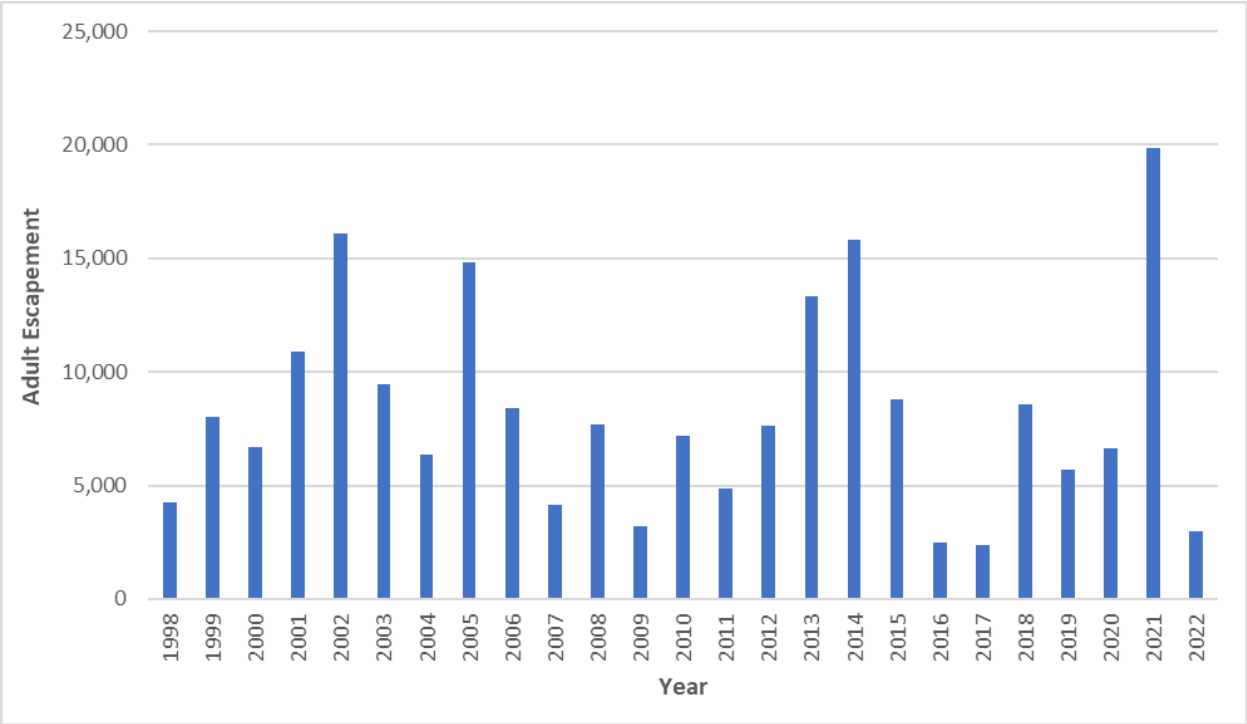
The actions of the CCRP have resulted in a near four-fold increase in escapement of fall-run Chinook salmon to Clear Creek (population estimate average = 1,749 from 1967 to 1991, and 7,333 from 1992 to 2017; Clear Creek Technical Team 2018). Late fall-run and fall-run Chinook salmon populations have increased since the initiation of restoration actions in 1995. Late Fall-run adult escapement from 2003–2022 ranged from 42 in 2006 to 336 in 2009 and averaged 110 (Figure O-2; Azat 2023). Fall-run adult escapement from 1998–2022 ranged from 2,353 in 2017 to 19,867 in 2021 and averaged 8,249 (Figure O-3; Azat 2023).

Available adult return data for fall-run and late fall-run Chinook salmon for the last couple decades are illustrated in Figure O-2 and Figure O-3 (note Y-axes are on different scales). Also, Figure O-2 does not show counts for 2000-2002, which were zero.



Source: Azat 2023.

Figure O-2. Late Fall-run Chinook Salmon Escapement, 2003–2022



Source: Azat 2023.

Figure O-3. Fall-run Chinook Salmon Returns, 1998–2022

Based on carcass surveys and juvenile out-migration trapping, fall-run Chinook salmon typically spawn in Clear Creek from late September through early December, and peak emigration of juveniles occurs in January and February (Earley et al. 2013). Late fall-run spawning in Clear Creek is likely similar to the Sacramento River, January through April. Juvenile late fall-run typically emerge from gravel and rear in freshwater for one month to seven months (Moyle 2002).

Fall- and late fall-run Chinook salmon generally out-migrate from Clear Creek as age-0 fish, although some (8.3% in 2011) late fall-run Chinook salmon juveniles out-migrate in their second year. Out-migration is generally from April to June for late fall-run and November to May for fall-run Chinook salmon. During the most recent year for which there are records (2011), the peak out-migration for fall-run in Clear Creek was in late December and the late fall-run peak out-migration was from mid-April to mid-May (Schraml et al. 2018).

Steelhead, California Central Valley DPS and Rainbow Trout

Central Valley steelhead have re-established in Clear Creek following implementation of the CCRP. Adult Central Valley steelhead and non-anadromous rainbow trout (*O. mykiss*) are present in Clear Creek. In Clear Creek, *O. mykiss* >16 inches have been seen migrating upstream through video monitoring as early as August and through February (Killam 2022). Adult Central Valley steelhead populations in Clear Creek were relatively stable from 2003 to 2011, with redd counts ranging from 42 to 409 and averaging 176 (Giovannetti et al. 2013; Provins and Chamberlain 2019b).

Construction of redds provide observations of spawning, although redd data are not typically linked to life-history type and could be from anadromous or resident *O. mykiss*. Redd estimates on Clear Creek are observed through annual kayak surveys that start in December and span April and are documented in USFWS reports (Provins and Chamberlain 2019a, 2019b). Based on the number of redds observed, most spawning appears to occur near to the confluence with the Sacramento River, between RMs 6.5 and 0. The temporal distribution of the redd count data shows peak spawning occurring from December–January, with 90% of redds constructed by February. Redd construction tapers off in the month of March, and all redds have been constructed by the end of April. The lack of redds observed in December 2014 may be due to two storm events, given that increases in discharge lead to increased turbidity, redd scour, and reduction in visibility (Provins and Chamberlain 2019a). In Clear Creek, occurrence of yearlings and juveniles at the monitoring traps starts in November, and the last yearlings and juveniles are detected in June (Schraml and Chamberlain 2019a, 2019b, 2020, 2021).

Pacific Lamprey

For general life history information applicable to all Central Valley rivers and tributaries inhabited by Pacific lamprey, see Section O.1.3.3, *Pacific lamprey*.

Pacific lamprey are assumed to occur throughout the accessible portion of Clear Creek downstream of Whiskeytown Dam. Although the extent of spawning is unknown, the species spawns in Clear Creek as evidenced by ammocoetes routinely collected in the screw trap at RM 1.7. During the 2011 collection season, a total of 320 lamprey ammocoetes were collected throughout the sampling season, with peaks in December 2010 and June 2011. In addition, 220 Pacific lamprey transformers (stage between larva and juvenile; see Clemens 2019) were collected throughout the sampling season with peak passage in December 2010 (Schraml et al. 2018). Presumably, current lamprey abundance is less than historical abundance due to the same factors that have reduced anadromous salmonid abundance (e.g., blocked passage, habitat alteration, etc.).

Pacific lamprey life cycles in Clear Creek are assumed to follow those elsewhere in the species range. Adult Pacific lampreys are thought to remain in the ocean for approximately 18 to 40 months before returning to freshwater as sexually immature adults, typically from late winter to early summer. The adults then hold for about a year in freshwater before spawning.

Hardhead

According to Moyle et al. 2015, hardhead mainly occupy canyon reaches and deep pools in Clear Creek. Hardhead are one of the non-target species part of the native fish assemblage regularly caught in the rotary screw traps in lower Clear Creek (Schraml and Chamberlain 2019a, 2019b, 2020, and 2021). For general life history information applicable to all Central Valley rivers and tributaries inhabited by hardhead, see Section O.1.3.3, *Hardhead*.

O.1.5.3 Whiskeytown Reservoir

Whiskeytown Reservoir is located within the Clear Creek watershed, which eventually flows to the Sacramento River. A small portion of water stored in Trinity Reservoir and Lewiston Dam is diverted through the Clear Creek Tunnel into Whiskeytown Reservoir.

Fish in Whiskeytown Reservoir and Upper Clear Creek

Whiskeytown Reservoir and some tributaries have been stocked by the CDFW with rainbow trout, brown trout, and Kokanee salmon. Other introduced species include largemouth bass, smallmouth bass, spotted bass, Alabama bass, bluegill, black crappie, brown trout, brook trout, channel catfish, and brown bullhead. Whiskeytown Reservoir also contains native fish species including Sacramento pikeminnow, hardhead, riffle sculpin, Western sucker, and rainbow trout (National Park Service 1999).

Hardhead (*Mylopharodon conocephalus*) is a California Species of Special Concern that occurs upstream of Whiskeytown Dam in Whiskeytown Reservoir and several of its tributaries.

Although there are federal ESA-listed spring-run Chinook salmon and California Central Valley steelhead and non-federal ESA-listed fall / late fall run Chinook salmon in Clear Creek below Whiskeytown Dam, there are no federally listed fish species in Whiskeytown Reservoir because Whiskeytown Dam does not have upstream fish passage facilities.

O.1.5.4 Aquatic Habitat

Historically, fish habitat in Clear Creek was negatively affected by Whiskeytown Dam, Saeltzer Dam, placer and dredger gold mining, in-stream aggregate mining, road-related erosion, and decades of fire suppression (Bureau of Land Management and National Park Service 2008).

Since 1995, the CVPIA and the CALFED Bay-Delta Program have undertaken anadromous salmonid habitat and flow restoration actions in Clear Creek. The actions have re-established salmon and steelhead populations within the Clear Creek watershed (Clear Creek Technical Team 2018). Actions have included rehabilitation of sediment transport and stream channel movement processes which help create and maintain spawning and rearing habitat. Also, the Saeltzer Dam was removed improving fish passage.

Spawning Habitat

All coarse and fine sediment from the upper watershed is trapped by the reservoir behind Whiskeytown Dam. The resulting coarse sediment deficit and reduction in fisheries habitat quality in lower Clear Creek was well documented (Bureau of Land Management and National Park Service 2008). Effects of reduced sediment supply included: riffle coarsening, fossilization of alluvial features, loss of fine sediments available for overbank deposition and riparian regeneration, and a reduction in the amount and quality of spawning gravels available for anadromous salmonids.

To combat the elimination of gravel recruitment from upstream of Whiskeytown Dam, spawning gravels have been added to Clear Creek downstream of Whiskeytown Dam every year since 2002. The gravel augmentation program on Clear Creek continues to enhance the spawning habitat available to fall- and spring-run Chinook salmon and steelhead (Bureau of Land Management and National Park Service 2008).

Spawning habitat is assessed by direct observation of the habitat used by spring-run Chinook salmon and steelhead for spawning. The proportional use of injected gravels vs. native gravels has steadily increased. In 2017, over 90% of steelhead and about 60% of the spring-run Chinook salmon that spawned in Clear Creek, upstream of the segregation weir, spawned on gravel that had been injected into the system (Clear Creek Technical Team 2018).

Rearing Habitat

The USFWS (2015) compared the total amount of rearing habitat available for spring-run Chinook salmon and steelhead to the amount of rearing habitat needed to support an annual escapement of 833 adults for each species (the target populations for Clear Creek). For fall-run Chinook salmon, available habitat was compared to the amount of habitat needed to support an average escapement of 7,920. At all modeled flows, habitat availability is greater than the current habitat needs for all life stages (including rearing) of Central Valley steelhead and Central Valley spring-run Chinook salmon, and estimated to be below the needs for fall-run Chinook salmon (U.S. Fish and Wildlife Service 2015).

The amount of rearing habitat for the various species and life stages in Clear Creek is highly related to flow (discharge). In general, the instream flow study by the USFWS found that fry and juvenile rearing habitat for all species and life stages peaked at flows higher than are typically provided by Whiskeytown Dam, but rearing habitat is currently more than adequate at all modeled flows to support the target populations of spring-run Chinook salmon and steelhead (2013, 2015). It was therefore determined that instream flow needs for physical habitat should be based on fall-run Chinook salmon due to its much higher population levels. The USFWS found that no flow from 50 cfs to 900 cfs would meet the habitat needs for rearing or other life stages of fall-run Chinook salmon. For example, a 200 cfs flow would meet approximately 70% of the spawning need, 40% of the juvenile rearing need, and 30% of the fry rearing need. The authors stated that adaptive management of the flow regime and habitat restoration coupled with long-term monitoring should be an effective strategy to address salmon species recovery.

O.1.5.5 Fish Passage

Whiskeytown Dam blocks access to 25 miles of historical spring-run Chinook salmon and steelhead spawning and rearing habitat. Prior to 2000, the McCormick-Saeltzer Dam was a barrier to upstream migration for anadromous salmonids. Its removal opened an additional 12 miles of habitat for anadromous fish. The McCormick-Saeltzer Dam removal contributed to the re-establishment of spring-run Chinook salmon and steelhead in Clear Creek. After the removal of the dam, a berm of cleaned spawning gravel was constructed downstream from the dam site to retain additional sediment. Although armored with rocks, this berm was expected to wash out in winter flows. Instead, it created a new barrier to spring-run Chinook salmon. Consequently, the California Department of Water Resources (DWR) removed the armoring and disbursed the berm in 2001.

O.1.6 Lower American River

The American River watershed encompasses approximately 2,100 square miles (Bureau of Reclamation et al. 2006). The three forks of the American River (north, middle, and south forks) converge upstream of Folsom Dam, with the combined flow moving through Lake Natoma and the lower American River for about 23 miles before entering the Sacramento River.

Water surface elevations in Folsom Reservoir vary annually as a result of seasonal inflow and water release and are generally the least variable during spring and most variable during summer (U.S. Army Corps of Engineers et al. 2012). Nimbus Dam creates Lake Natoma, which serves as a regulating afterbay to the Folsom Power Plant, maintaining more uniform flows in the lower American River. Lake Natoma is a shallow reservoir with an average depth of about 16 feet (Bureau of Reclamation 2005). Surface water elevations in Lake Natoma may fluctuate four feet to seven feet daily (U.S. Army Corps of Engineers et al. 2012).

O.1.6.1 Water Operations Management

Flow

Reclamation operates the CVP American River Division for flood control, municipal and industrial (M&I) and agricultural water supplies, hydroelectric power generation, fish and wildlife protection, recreation, and Delta water quality. Facilities include the Folsom Dam, Folsom Reservoir (977 thousand acre-feet [TAF] capacity), power plant, urban water supply temperature control device, and the Joint Federal Project auxiliary spillway as well as Nimbus Dam, Lake Natoma, Nimbus Power Plant, and Folsom South Canal. Folsom Reservoir is the main storage and flood control reservoir on the lower American River. Numerous other smaller reservoirs in the upper basin provide hydroelectric generation and water supply without specific flood control responsibilities. The total upstream reservoir storage above Folsom Reservoir is approximately 820 TAF, and these reservoirs are operated primarily for hydropower production. Ninety percent of this upstream storage is contained by five reservoirs: French Meadows (136 TAF); Hell Hole (208 TAF); Loon Lake (76 TAF); Union Valley (271 TAF); and Ice House (46 TAF). Reclamation coordinates with the operators of these reservoirs to aid in planning for Folsom Reservoir operations. Releases from Folsom Dam are re-regulated approximately seven miles downstream by Nimbus Dam. Nimbus Dam creates Lake Natoma, which serves as a forebay for diversions to the Folsom South Canal. Releases from Nimbus Dam to the lower American River pass through the Nimbus Power Plant, or the spillway gates at flows in excess of 5,000 cfs. Because Folsom Reservoir is the closest reservoir to the Delta, releases from Folsom Reservoir can address Delta water quality requirements under D-1641 more quickly than releases from other CVP facilities.

Reclamation, operating under the Water Board Decision 893 (D-893) adopted in 1958, allows flows at the mouth of the American River to fall as low as 250 cfs from January through mid-September, with a minimum of 500 cfs required between September 15 and December 31. The D-893 flow schedule does not address the more recent requirements of the CVPIA, the 1995 Bay-Delta Plan, or biological opinions issued to protect steelhead. Reclamation and the Water Board and many stakeholders (Water Forum) agreed that D-893 did not provide sufficient protections for steelhead in the lower American River. Recently, Reclamation has operated the

Folsom/Nimbus complex to more modern protective requirements and habitat management plans by providing flows that far exceed those required in D-893.

Current flow operations are according to the MFR established in the 2006 Water Forum Lower American River Flow Management Standard (Water Forum 2006) as modified by the American River Water Agencies Modified Flow Management Standard (American River Water Agencies 2017). The MFR establishes minimum flows, as measured by the total release at Nimbus Dam, which vary throughout the year in response to the hydrology of the Sacramento and American River basins. The October 1 through December 31 MFR range between 800 and 2,000 cfs. The January 1 through Labor Day MFR range between 800 and 1,750 cfs. The post-Labor Day through September MFR range between 800 and 1,500 cfs. As a general rule, the MFR must equal or exceed 800 cfs year-round. Narrowly defined exceptions to this rule allow Nimbus Dam releases to drop below 800 cfs to avoid depletion of water storage in Folsom Reservoir when dry or critical hydrologic conditions are forecasted to occur. These narrowly defined exceptions to the MFR are an important component of the 2006 Flow Management Standard. The purpose of the 2017 Modified Flow Management Standard is to further improve conditions for fall-run Chinook salmon and steelhead and reduce the risk of dead pool conditions in Folsom Reservoir while avoiding redirected impacts to Sacramento River salmonids.

Water Temperature

Water temperatures in the lower American River are influenced by the timing, volume, and temperature of water releases from Folsom and Nimbus dams, and are currently managed according to the water temperature objectives established in the 2006 Flow Management Standard as modified by the Modified Flow Management Standard (American River Water Agencies 2017). The water temperature objectives comply with the targets identified in the NMFS Biological Opinion (2004) for the Long-Term CVP and SWP Operations and Criteria Plan, which are intended to minimize water temperature effects on steelhead, including the lower American River. Under the primary water temperature objective, Reclamation operates the Folsom/Nimbus Dam complex and the water temperature control shutters at Folsom Dam are used to maintain a daily average water temperature of 65°F or lower at Watt Avenue Bridge from May 15 through September 30, reduced to 60°F by October 15, and 56°F by November 1. Subsequent objectives provide measures minimizing temperature effects if the primary objective cannot be achieved. The water temperature objectives are achieved according to an annual Temperature Plan, which is prepared in accordance with the water temperature objectives and is designed to minimize water temperature effects on Central Valley steelhead and provide for Chinook salmon spawning in the fall.

O.1.6.2 Lower American River between Lake Natoma and the Sacramento River

The lower American River extends approximately 23 miles from Nimbus Dam downstream to the confluence with the Sacramento River. Access to the upper reaches of the river by anadromous fish is blocked at Nimbus Dam.

Fish Evaluated in the Lower American River

The lower American River system supports numerous resident native and introduced species as well as several anadromous species.

The analysis is focused on the following species:

- Winter-run Chinook salmon
- Fall-run Chinook salmon, Central Valley ESU
- Steelhead, California Central Valley DPS
- White sturgeon
- Sacramento splittail
- Pacific lamprey
- Western river lamprey
- American shad
- Threadfin shad
- Striped bass
- Black basses

Winter-run Chinook Salmon, Sacramento River ESU

Genetically-confirmed juvenile winter-run Chinook salmon have been caught in rotary screw traps in the lower American River at Watt Avenue in most years between 2014 and 2021 (Day 2022). Based on otolith micro-chemistry, Phillis et al. (2018) estimated that between 17% and 26% of all winter-run Chinook salmon juveniles in the Central Valley rear in the American River. These individuals are thought to have spawned outside the American River and moved with high Sacramento River flows backing up into the American River (Phillis et al. 2018).

Fall-run Chinook Salmon, Central Valley ESU

Historically, the American River supported fall-run and perhaps late fall-run Chinook salmon (Williams 2001). Both natural-origin and hatchery-produced Chinook salmon spawn in the lower American River. Analysis by Palmer-Zwahlen et al. (2018) indicated that the most recently available constant fractional marking results from 2013 show approximately 86% of the fall-run Chinook salmon spawners in the lower American River returning to the hatchery are hatchery-origin. In addition, 71% of fall-run Chinook salmon counted at the Hatchery Weir are of hatchery origin and 65% of carcasses were also identified as of hatchery origin.

Adult fall-run Chinook salmon enter the lower American River from about mid-September through January, with peak migration from approximately mid-October through December (Williams 2001). Spawning occurs from about mid-October through early February, with peak spawning from mid-October through December. Chinook salmon spawning occurs within an 18-mile stretch from Paradise Beach to Nimbus Dam; however, most spawning occurs in the uppermost 3 miles (California Department of Fish and Wildlife 2012a). Chinook salmon egg and alevin incubation occurs in the lower American River from about mid-October through April. There is high variability from year to year; however, most incubation occurs from about mid-October through February. Chinook salmon fry emergence occurs from January through mid-

April, and juvenile rearing extends from January to about mid-July (Williams 2001). Most Chinook salmon out-migrate from the lower American River as fry from December to July; out-migration peaks in February and March (Snider and Titus 2002; Pacific States Marine Fisheries Commission 2014).

Steelhead, California Central Valley DPS

Adult steelhead will migrate into the lower American River in the fall and winter and spawn in winter and spring. Anadromous steelhead will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). In the lower American River, redd surveys have reported spawning January through April, with peak spawning in February (Sweeney et al. 2021). Due to their varying life-history strategies and iteroparity, migrating adult steelhead are difficult to monitor using the same strategies employed for Chinook salmon in the Central Valley. In the lower American River, adult steelhead start arriving at Nimbus Fish Hatchery in November and continue through April (California Department of Fish and Wildlife 2023c). Spawning density is highest in the upper 7 miles of the river, but spawning occurs as far downstream as Paradise Beach. About 90% of spawning occurs upstream of the Watt Avenue Bridge (Hannon and Deason 2008). Adult steelhead are iteroparous, although repeated spawning rates of anadromous individuals are considered low in populations in the Central Valley (Null et al. 2013).

While there is natural spawning of steelhead in the lower American River, the population is supported primarily by the Nimbus Fish Hatchery. Sweeney et al. (2022) reported steelhead returns at Nimbus Fish Hatchery and in-river spawner estimates for years 2002 through 2022. Much greater numbers returned to the hatchery, when compared to in-river spawner estimates, among all years. Annual averages were 1,537 and 217 for hatchery returns versus in-river spawner estimates, respectively. Both metrics were noticeably higher for years 2002 through 2013 when compared to years 2014 through 2022. Lindley et al. (2007) classifies the listed (i.e., naturally spawning) population of lower American River steelhead at a high risk of extinction because it is reportedly mostly composed of steelhead originating from Nimbus Fish Hatchery. NMFS views the lower American River population as important to the survival and recovery of the species (National Marine Fisheries Service 2009a).

Nielsen et al. (2005) found steelhead in the American River to be genetically different from other Central Valley stocks. Eel River steelhead were used to establish the Nimbus Hatchery stock, and steelhead from the American River (collected from both the Nimbus Fish Hatchery and the American River) are more closely related to Eel River steelhead than other Central Valley steelhead stocks. Based on studies by Hallock et al. (1961), Staley (1976), Nielsen et al. (2005), and Lee and Chilton (2007) reported that American River winter-run steelhead are genetically and phenotypically different from other Central Valley steelhead populations and demonstrate a later upstream migration period. Zimmerman et al. (2009) noted that there remains a strong resident component (i.e., fish that do not migrate to the ocean) of the *O. mykiss* population that interacts with and produces anadromous individuals. Steelhead and rainbow trout are the same species and when juveniles of the species are found in freshwater, it is unclear if they will exhibit an anadromous (steelhead) or resident (rainbow trout) life history strategy. Thus, they are often collectively referred to as *O. mykiss* at this stage to indicate this uncertainty.

Embryo incubation begins with the onset of spawning in January and generally extends through May, with peak incubation between March and May (Hannon pers. comm.). Steelhead embryo and alevin mortality associated with high flows in the American River has not been documented, but historically flood releases have been high enough to mobilize spawning gravels do occur during the spawning and embryo incubation periods (National Marine Fisheries Service 2009a).

Juvenile *O. mykiss* have been documented year-round throughout the lower American River, with rearing generally upstream of spawning areas. Juvenile steelhead rear in freshwater habitats for one to four years before emigrating to the ocean. Both spawning areas and migratory corridors are used by juvenile steelhead for rearing prior to outmigration (National Marine Fisheries Service 2009a). Juveniles reportedly can rear in the lower American River for a year or more before out-migrating as smolts from January through June (Snider and Titus 2000a; Surface Water Resources 2001). However, annual reports by the Pacific States Marine Fisheries Commission often report low captures of yearlings, with only one yearling in 2022, 402 YOY fry and parr, and one post-spawn kelt (Day and Morris 2022). Peak out-migration occurs from March through May (McEwan and Jackson 1996; Surface Water Resources 2001; Pacific States Marine Fisheries Commission 2014). Stationary monitoring systems designed for studying Chinook salmon have low capture efficiencies for collecting juvenile *O. mykiss* smolts, as steelhead will typically outmigrate larger and have stronger swimming abilities when compared to juvenile Chinook salmon (Eschenroeder et al. 2022).

Rearing habitat for juvenile steelhead in the lower American River occurs throughout the upper reaches downstream to Paradise Beach. In summer, juveniles occur in most major riffle areas, with the highest concentrations near the higher density spawning areas (Bureau of Reclamation 2008). The number of juveniles in the American River decreases throughout summer (Bureau of Reclamation 2008). Warm water temperatures stress juvenile steelhead rearing in the lower American River, particularly during summer and early fall (Lower American River Task Force 2002; Water Forum 2005c; National Marine Fisheries Service 2014c). However, laboratory studies suggest that American River steelhead may be more tolerant of high temperatures than steelhead from regions farther north (Myrick and Cech 2004).

Pacific Lamprey

The Pacific lamprey inhabits accessible reaches of the American River. Information on the status of Pacific lamprey in the American River is limited, but the loss of historical habitat and apparent population declines throughout California indicate populations are greatly decreased compared to historical levels (Moyle et al. 2009).

Hannon and Deason (2008) documented Pacific lamprey spawning in the American River from early January to late May, with peak spawning typically occurring in early April. Pacific lamprey ammocoetes rear in the American River for all or part of their 3- to 7-year freshwater residence. Data from rotary screw trapping in the nearby Feather River suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006), although some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006) and in other river systems (Moyle 2002).

Because of the parallels in their life cycles, particularly spawning, lampreys may be affected by many of the same factors as salmon and steelhead. Little information is available on factors influencing Pacific lamprey populations in the lower American River, but the dams likely play an important role. Moyle et al. (2009) suggested that in addition to blocking upstream migration, dams may disrupt upstream sediment inputs required to maintain habitat for ammocoetes and subject ammocoetes to rapid decreases in stream flow. Moyle et al. (2009) also indicated that ramping rates sufficient to protect salmonids may not be adequate to prevent the stranding of ammocoetes and metamorphosing individuals, which are vulnerable to desiccation and avian predation. Additionally, commercial harvest of lampreys on the American River (presumably for bait) may reduce spawning success in some years (Hannon and Deason 2008).

Western River Lamprey

Western river lamprey have been collected in the American River and Mill and Cache Creeks but their overall abundance and distribution in the lower American River is poorly understood (Vladykov and Follett 1958; Hanni et al. 2006; Moyle et al. 2009).

The life history of river lamprey is also understudied, especially in California (Moyle et al. 2015). The adults seem to migrate from the ocean to spawning areas during the fall and late winter (Beamish 1980). Spawning is believed to occur February through May in small tributary streams (Moyle 2002). The redds are built at the upstream end of small riffles (Moyle 2002). After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002).

River flow potentially affects survival of river lamprey eggs and larvae, and migratory habitat of the juveniles and adults. River lamprey build their spawning redds in shallow water (Moyle et al. 2015), so reductions in water level can dewater the redds. Assuming river lamprey larvae habitat requirements are similar to those of Pacific lamprey, the larvae select habitats that are often off-channel, with low flow velocity and shallow depths; therefore, they are vulnerable to stranding by reductions in water level. For general life history information applicable to all Central Valley rivers and tributaries inhabited by green sturgeon, see Section O.1.3.3, *Green Sturgeon, Southern DPS*.

Sacramento Splittail

Splittail likely spawn in the lower reaches of the American River (Sommer et al. 2008; Moyle et al. 2004). Because upstream migration is more directed and fish tend to swim farther upstream during wet years (Moyle 2002), more individuals are expected to use the lower American River in wet years. Although juvenile splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks of rearing on floodplain habitat (Bureau of Reclamation 2008). Most juveniles move downstream into the Delta from April to August (Meng and Moyle 1995). The primary factor potentially limiting the American River population of Sacramento splittail is availability of inundated floodplains for spawning and rearing habitats (Moyle et al. 2004). For general life history information applicable to all Central Valley rivers and tributaries inhabited by splittail, see Section O.1.3.3, *Sacramento Splittail*.

Hardhead

Hardhead are fairly common year-round in the lower reaches of the American River (Moyle 2002). Although migratory behavior of hardhead in the American River individuals is unknown, individuals from other large rivers, such as the Sacramento River, migrate into tributary streams during April and May and typically spawn between April and May (Moyle 2002). For general life history information applicable to all Central Valley rivers and tributaries inhabited by hardhead, see Section O.1.3.3, *Hardhead*.

White Sturgeon

Limited quantitative information is available on the distribution and status of white sturgeon in the American River; however, small numbers of adults apparently use the lower American River, as evidenced by sturgeon report cards submitted to the CDFW by anglers in recent years (e.g., DuBois et al. 2020). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *White Sturgeon*.

American Shad

American shad are a recreationally important anadromous species introduced into the Sacramento and San Joaquin River Basins in the 1870s (Moyle 2002). American shad spend most of their adult life at sea and may make extensive migrations along the coast. They become sexually mature while in the ocean and migrate through the Delta to spawning areas in the in the lower American River. The spawning migration may begin as early as February, but most adults migrate into the Delta in March and early April (Skinner 1962). Migrating adults generally take 2 to 3 months to pass through the Delta (Painter et al. 1979). Adult American shad migrate into the lower American River to spawn during the late spring, typically during April through early July (California Department of Fish and Wildlife 1986). During this period, they provide an important sport fishery. The shortage of adequate attraction flows in major tributaries such as the American River may be contributing to declines in the population (Moyle 2002). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *American Shad*.

Threadfin Shad

Threadfin shad were introduced in reservoirs throughout California to provide forage for game fish, with the Sacramento and San Joaquin River Basins introductions starting as early as 1959. From these transplants, they have become established in the Sacramento–San Joaquin River system and the Delta. Threadfin shad are occasionally captured as part of the non-salmonid bi-catch in the rotary screw traps in the lower American River (Pacific States Marine Fisheries Commission 2014). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Threadfin Shad*.

Striped Bass

Striped bass are present in the American River throughout the year, with the greatest abundance in summer (Surface Water Resources 2001). Although the occurrence of spawning in the American River is uncertain, the river is believed to serve as a nursery area for YOY and subadult striped bass (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally

important sportfishing resource. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Striped Bass*.

Black Basses

All three species of black basses, largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species), are found in the lower American River, Lake Natoma, and Folsom Reservoir. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Black Basses*.

O.1.6.3 Folsom Reservoir and Lake Natoma

Folsom Reservoir has a capacity of approximately 977,000 acre-feet, and primarily collects water from the North Fork and South Fork of the American River. The reservoir serves as a flood control facility for runoff in the lower American River as well as a regional destination for aquatic recreation, which includes fishing and boating. Lake Natoma is downstream of Folsom Reservoir and serves as a regulating reservoir for releases from Folsom Reservoir as well as a recreational facility supporting year-round recreational opportunities.

Fish in Folsom Reservoir and Lake Natoma

Thermal stratification of the reservoir generally begins during April and usually persists throughout summer until November, when cooler temperatures, winter rains, and high inflows create mixing and result in "turnover" (Bureau of Reclamation 2005; U.S. Army Corps of Engineers et al. 2012). During summer, a thermocline develops that separates the epilimnion (i.e., upper layer of warm water) and the hypolimnion (i.e., lower layer of cooler water). This thermal stratification and segregation of habitats allow for both cold water and warm water species to coexist in Folsom Reservoir (U.S. Army Corps of Engineers et al. 2012). Warm water fish species include native hardhead, Central California roach, Sacramento pikeminnow, and Sacramento sucker, as well as nonnative largemouth bass, smallmouth bass, spotted bass, sunfish, black crappie, and white crappie (Bureau of Reclamation 2007). Cold water fish species include native rainbow trout and planted Chinook salmon and Kokanee salmon, as well as nonnative brown trout (Bureau of Reclamation 2007). Lake Natoma has relatively low productivity as a fishery due to the effects of wide water temperature variability associated with the lake's fluctuating elevation. Reclamation (2007) reports that fish species found in Lake Natoma are generally the same as those in Folsom Lake. Although the CDFW annually stocks Lake Natoma with hatchery rainbow trout, conditions in Lake Natoma are more favorable for warm water fish species (Bureau of Reclamation 2007).

O.1.6.4 Aquatic Habitat

Since 1955, Nimbus Dam has blocked upstream passage by anadromous fish and restricted available habitat in the lower American River to the approximately 23 RMs between the dam and the confluence with the Sacramento River. Additionally, Folsom Dam has blocked the downstream transport of sediment that contributes to the formation and maintenance of habitat for aquatic species.

In 2008, Reclamation, in coordination with the USFWS and Sacramento Water Forum, began implementation of salmonid habitat improvement in the lower American River. The program has evolved over time and currently consists of 10 separate implementation areas concentrated in the upper portion of the LAR between river mile (RM) 12.9 and 22.3 (USACE river miles).

Past projects have included the placement of designed gravel features (i.e., spawning riffles, islands, and bars), in-stream habitat features (e.g., large woody material installations), and enhancement or creation of seasonally inundated channel margin/benches/alcove rearing habitat and/or perennial side channels. Designed habitat features take advantage of natural river dynamics to provide synergy for spawning and rearing habitat areas (i.e., the placement of designed gravel features) and can serve to increase the inundation frequency of existing channel margins and/or constructed side channels. To optimize habitat enhancement opportunities, multiple complementary elements are often used in combination for any given project. Additionally, in a dynamic river with little to no coarse sediment input from the upper watershed, restored sites must be maintained over time to ensure continued habitat effectiveness.

During higher flows, channel geomorphology in the lower American River is characterized by bar complexes and side channel areas, which may become limited at lower flows (National Marine Fisheries Service 2009a). Spawning bed materials in the lower American River may begin to mobilize at flows of 30,000 cfs, with more substantial mobilization at flows of 50,000 cfs or greater (Bureau of Reclamation 2008). At 115,000 cfs (the highest flow modeled), particles up to 70 mm median diameter would be moved in the high-density spawning areas around Sailor Bar and Sunrise Avenue. Flood frequency analysis for the lower American River at the Fair Oaks gage shows that, on average, flood control releases exceed 30,000 cfs about once every four years and exceed 50,000 cfs about once every five years (Bureau of Reclamation 2008).

Reclamation's habitat restoration efforts also included the side channels at Upper Sunrise and Lower Sunrise, which were identified as a suitable site for steelhead spawning habitat restoration. In 2008, the CVPIA (b)(13) program cut and widened the Lower Sunrise side channel so that it inundated through a greater range of flows. The project reduced steelhead stranding, but also inadvertently reduced Chinook salmon and steelhead spawning and rearing habitat (Anadromous Fish Restoration Program 2012). Consequently, the Upper Sunrise main channel was filled at the head-cut to create greater head pressure, thereby allowing flow once again through the side channels. Monitoring at the Upper Sunrise project revealed immediate response from Chinook salmon and steelhead moving up into the side channel to spawn after completion of the project. Spawning and rearing habitat enhancement projects occurred nearly every year from 2008 through 2023 in the reach from Nimbus Dam down to River Bend Park. Years during which no implementation occurred were due to funding and/or regulatory constraints. These annual projects are planned to continue at least through 2034, which is the current duration of the programmatic regulatory compliance documentation obtained for the program in 2022.

Spawning and rearing habitat restoration activities include primarily side channel and floodplain creation, expansion, and grading, spawning gravel and large cobble additions, and woody material additions (Reclamation 2024). As of WY 2022, 13.5 acres of rearing habitat and 4.9 acres of spawning habitat were completed in lower sailor bar, and 2.5 acres of rearing habitat and 3.7 acres of spawning habitat were completed in the Nimbus Basin. There are on-going efforts to

create 6 acres of rearing habitat and 5 acres of spawning habitat in the Upper River Bend that are anticipated to finish in 2024.

O.1.6.5 Fish Passage

Including the mainstem, north, middle, and south forks, more than 125 miles of riverine habitat historically were available for anadromous salmonids in the American River watershed (Yoshiyama et al. 1996). Access to the upper reaches of the river has been blocked by a series of impassable dams, including Old Folsom Dam, which first impounded the American River from 1895 to 1939.

Reclamation operates a fish diversion weir approximately 0.25 mile downstream of Nimbus Dam, which functions to divert adult steelhead and Chinook salmon into Nimbus Fish Hatchery. The weir is annually installed during September prior to the arrival of fall-run Chinook salmon and steelhead and is removed at the conclusion of fall-run Chinook salmon immigration in early January (Bureau of Reclamation and California Department of Fish and Wildlife 2011). Some steelhead may be trapped prior to weir removal, but they are returned to the river. A new fish passageway is being implemented in the Nimbus Dam stilling basin, commonly referred to as Nimbus Shoals. The passageway will replace the existing fish diversion weir with a new flume and fish ladder that will connect to the existing fish ladder near Nimbus Fish Hatchery.

O.1.6.6 Hatcheries

The CDFW operates the Nimbus salmon and steelhead Hatchery and American River Trout Hatchery, located immediately downstream from Nimbus Dam. Facilities associated with Nimbus Fish Hatchery include a fish weir, fish ladder, gathering and handling tanks, hatchery-specific buildings, and rearing ponds. Nimbus Fish Hatchery was constructed primarily to mitigate the loss of spawning habitat for Chinook salmon and Central Valley steelhead (regardless of unintended genetic differences, discussed earlier) that resulted from the construction of Nimbus Dam (Bureau of Reclamation and California Department of Fish and Wildlife 2011); it does not address lost habitat upstream from Folsom Dam (California Hatchery Scientific Review Group 2012). The hatchery operations include the trapping, artificial spawning, rearing, and release of steelhead and fall- /late fall-run Chinook salmon. Propagation programs for American River winter-run steelhead and Central Valley fall-/late fall-run Chinook salmon are operated by the CDFW under contract with Reclamation (Lee and Chilton 2007). The Nimbus Fish Hatchery Winter-run steelhead Program is an isolated-harvest program (i.e., it does not include natural-origin steelhead in the broodstock) designed and implemented to artificially spawn the adipose fin-clipped adult steelhead that seasonally enter the trapping facilities (California Hatchery Scientific Review Group 2012). These fin-clipped fish are not part of the Central Valley DPS steelhead. The Nimbus Fish Hatchery Winter-run steelhead Program propagates fish for recreational fishing opportunities and harvest (California Hatchery Scientific Review Group 2012).

Steelhead have been trapped at Nimbus Fish Hatchery as early as the first week of October; however, since 2000, the ladder has been opened in early November. Trapping of steelhead has continued to occur as late as the second week of March. Presently, winter-run steelhead are trapped at Nimbus Fish Hatchery, and artificially spawned adults are marked with an adipose fin clip (California Hatchery Scientific Review Group 2012). Unmarked steelhead adults are not

retained at Nimbus Fish Hatchery for use in the annual broodstock and are released back to the river (California Hatchery Scientific Review Group 2012). In addition, marked or unmarked *O. mykiss* that are less than 16 inches long may be resident hatchery-origin trout and are returned to the river (California Hatchery Scientific Review Group 2012).

On average, the program has raised and released approximately 430,000 yearling steelhead since brood year 1999 (California Hatchery Scientific Review Group 2012). Since 1998, all steelhead/rainbow trout produced in Nimbus Fish Hatchery have been marked with an adipose fin-clip to aid in subsequently identifying hatchery-origin fish.

Juvenile steelhead yearlings are not held past March 30 because of increasing hatchery water temperatures and to encourage out-migration during spring. If releases occur during periods of low flows in the Sacramento River and possibly the lower American River, some released fish migrate back to Nimbus Fish Hatchery and may take up residency rather than migrating downstream (Lee and Chilton 2007). Additionally, juvenile fish are released in February and early March to coincide with closures of the Delta Cross Channel gates to reduce straying into the Delta. Reclamation determines the exact timing and duration of the gate closures after discussion with the USFWS, CDFW, and NMFS.

Reclamation is developing a series of Hatchery and Genetic Management Plans for genetic screening of American River salmonid populations. In March 2021, Reclamation completed the HGMP project management plan for fall-run Chinook salmon followed by submission of the Project Work Statement to begin the contracting process in July 2021 (Delta Stewardship Council 2023). Once the fall-run HGMP is finished, the steelhead is anticipated to be completed next.

The CDFW releases all hatchery-produced steelhead juveniles into the American River at boat ramps on the American River or at the confluence of the Sacramento and American Rivers and releases all unclipped steelhead adults returning to Nimbus Fish Hatchery into the lower American River via the river return tube that is just downstream of the fish ladder. In accordance with California law, the current protocol of Nimbus Fish Hatchery is to destroy all surplus eggs to prevent inter-basin transfer of eggs or juveniles to other hatcheries or waters.

The goal of the Nimbus Fish Hatchery Integrated Fall-/Late Fall-run Chinook Salmon Program is to release 4 million smolts annually. Each fall, Nimbus Hatchery staff collect approximately 10,000 adult fall-run Chinook salmon, with an annual goal of harvesting 8,000,000 eggs and releasing the 4,000,000 smolts. In 2023, Nimbus Fish Hatchery released a record number of 5.5 million fall-run Chinook salmon, including an experimental 1.1 million fry for parentage-based tagging (California Department of Fish and Wildlife 2023e). Increases in production targets were implemented to help address issues related to drought and thiamine deficiency, which impact all runs of Chinook salmon. All adult fall-run Chinook salmon collected at the hatchery are euthanized, and no trapped salmon are returned to the American River (Bureau of Reclamation 2008).

O.1.6.7 Disease

The occurrence of a bacterial-caused inflammation of the anal vent (commonly referred to as "rosy anus") of steelhead in the lower American River has been reported by the CDFW to be associated with relatively warm water temperatures (Water Forum 2005b). Anal vent inflammation of steelhead in the lower American River was observed in 2004 during periods when water temperatures were measured from 65°F to 68°F (Water Forum 2005a, 2005b). The Water Forum (2005b) suggested that, in addition to possible diminished immune system responses and incidences of diseases associated with elevated water temperatures, disease transmission may be exacerbated by crowding under conditions when water flows are reduced.

O.1.6.8 Predation

Two factors, reduced coldwater storage in Folsom Reservoir and using Folsom Reservoir to meet Delta water quality objectives and demands, influence habitat conditions in the lower American River for warm water predator species that feed on juvenile salmonids and potentially alter predation pressure (Water Forum 2005b). Additionally, isolation of redds in side channels resulting from fluctuations in Folsom Reservoir releases may increase predation of emergent fry (Water Forum 2005b).

O.1.6.9 Harvest

Harvest for fall-run Chinook salmon in the American River consists of a combination of in-river recreational and ocean harvest. Fall-run Chinook salmon escapement to the American River are part of the Sacramento River fall-run Chinook salmon (SRFC) stock managed by the Pacific Fishery Management Council. Since March 2018, the section of river one and half miles below Nimbus dam has been permanently closed to all in-river fishing, which used to be a considerable portion of the harvest (PFMC 2022). The in-river sport fishery is monitored in several locations, including the American River, Feather River, lower Sacramento, and upper Sacramento River. In 2022, the estimated catch by anglers in the American River locations were approximately 33% of the total in-river harvest of 5,400 SRFC (Simkins et al. 2023). Escapement in 2022 in the American River basin was estimated at 22,942 adults and 2,964 jacks (Figure O-4; Dean 2023). Both in-river and ocean fisheries were closed in 2023. For more details on ocean harvest of the Sacramento River fall-run stock, see Section O.1.3.5.

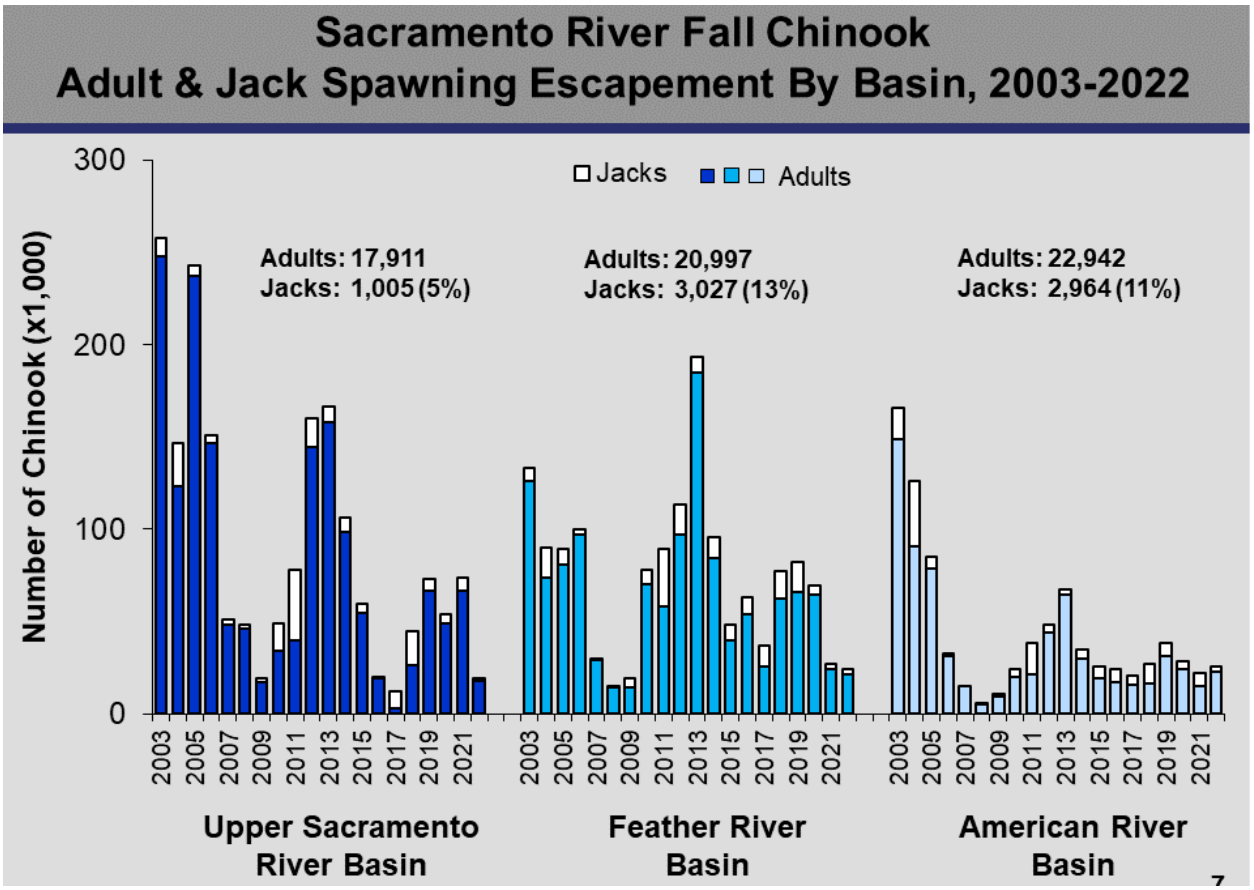


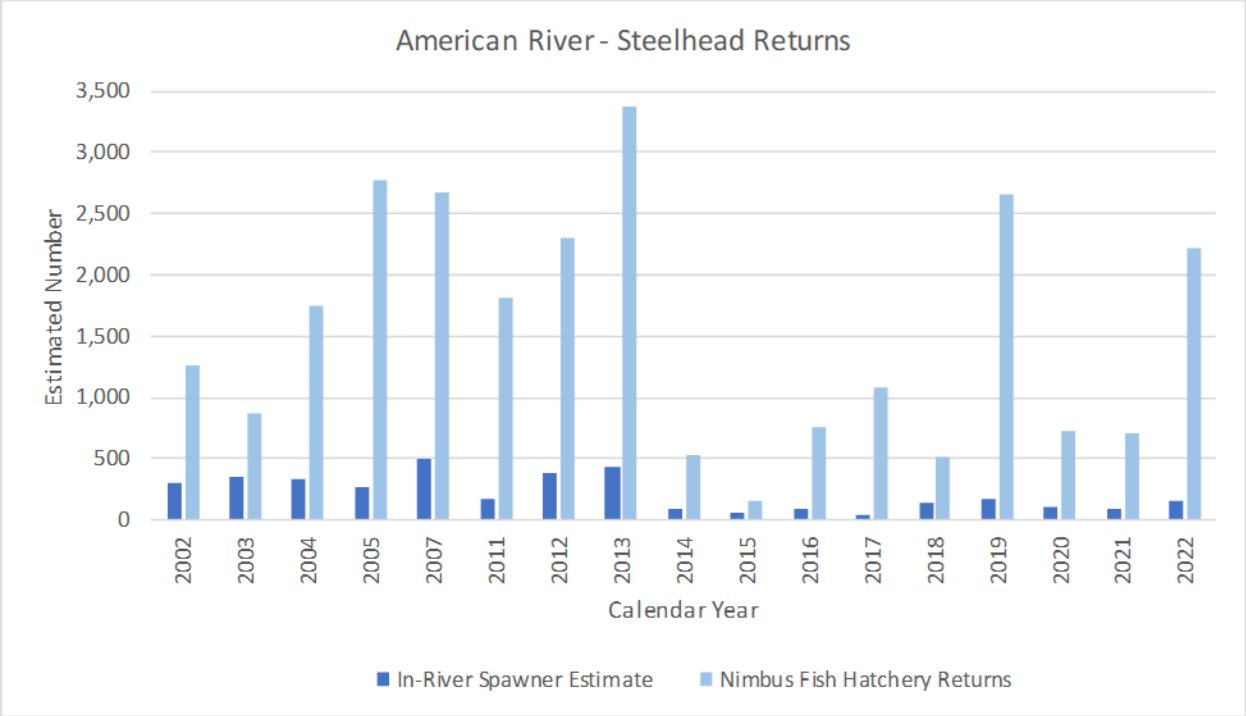
Figure O-4. Sacramento River Fall Chinook Salmon Escapement for the Upper Sacramento, Feather, and American River Basins

In-river harvest of California Central Valley steelhead in the American River is estimated through angler report cards. Take of steelhead in the ocean is prohibited. On average, 2,260 steelhead catch were reported between 2015-2019 (Table O-5). Between 2015 and 2019, the in-river spawner estimate and Nimbus Fish Hatchery returns ranged from 219 steelhead returning in 2015 to 2,835 steelhead returning in 2019 (Figure O-5).

Table O-5. All Steelhead Catch and Recorded Trips Within the American River and Tributaries Location Code From 2015–2019

Year	Wild Released	Hatchery Kept	Hatchery Released	Total Steelhead	Total Trips	Total Hours	Average Hours per Trip	Average Steelhead per Trip
2015	324	360	1,065	1,749	4,108	14,766	3.59	0.43
2016	300	207	671	1,178	2,360	7,939	3.36	0.50
2017	727	283	835	1,845	4,123	13,967	3.39	0.45
2018	865	254	935	2,054	3,982	13,414	3.37	0.52
2019	602	381	1,231	2,214	4,074	14,068	3.45	0.54
2015-2019	**2,818**	**1,485**	**4,737**	**9,040**	**18,647**	**64,154**	**3.44**	**0.48**
Avg	**705**	**371**	**1,184**	**2,260**	**4,662**	**16,039**		

Source: California Department of Fish and Wildlife 2021.



Source: Sweeney et al. 2022.

Figure O-5. Steelhead Nimbus Hatchery Returns and In-River Spawner Estimates, American River, 2002–2022

O.1.7 Stanislaus River

O.1.7.1 Water Operations Management

Flow

Reclamation operates the CVP East Side Division for flood control, agricultural water supplies, hydroelectric power generation, fish and wildlife protection, and recreation. In the Stanislaus River watershed, Reclamation owns and operates New Melones Dam and Reservoir (2.4 million acre-feet capacity). The Tri-Dam Project, a partnership between the Oakdale Irrigation District (OID) and South San Joaquin Irrigation District (SSJID), consists of Donnells and Beardsley Dams, located upstream of New Melones Reservoir on the Middle Fork Stanislaus River, and Tulloch Dam and Powerplant, located approximately six miles downstream of New Melones Dam on the mainstem Stanislaus River. Releases from Donnells and Beardsley Dams affect inflows to New Melones Reservoir. The main water diversion point on the Stanislaus River is Goodwin Dam, located approximately two miles downstream of Tulloch Dam. OID and SSJID manage the Tulloch and Goodwin Dam infrastructure through separate agreements with both Reclamation and Reclamation's CVP water service contractors (Stockton East Water District and the Central San Joaquin Water Conservation District) to meet Reclamation's Stanislaus River objectives, CVP contractor deliveries, and deliveries to the OID and SSJID service areas.

The Stanislaus River watershed has annual obligations that exceed the average annual runoff in a given year due to a number of factors, including Water Board water rights decisions D-1641, D-1422 and D-1616, the 1987 California Department of Fish and Game (now CDFW) agreement, CVPIA objectives, the 2019 Biological Opinion, the 1988 Agreement and Stipulation with OID and SSJID, riparian water right diverters, and CVP water delivery contracts.

Over the past decade, Reclamation has worked with Stanislaus River water users and related agencies in developing a revised operating plan for New Melones Reservoir that addresses multiple objectives, including a more predictable and sustainable operation, minimizing low storage conditions in successive drought years, and providing flows to support listed species and critical habitat. These efforts have allowed multiple agencies to provide input on potential solutions.

As described in Appendix 2-E, *Stanislaus River Minimum Flows for Fish Needs*, of the 2011 NMFS RPA (National Marine Fisheries Service 2011a) Reclamation was required to operate releases from the East Side Division reservoirs according to the New Melones year-type specific minimum flow schedules. Table O-6 through Table O-9 indicate the specific minimum flow schedule that Reclamation currently operates for the East Side Division reservoir. The flow is based on releases measured at Goodwin Dam. However, the flow schedule does not preclude Reclamation from making higher releases for fishery benefits or other operational criteria.

In the 2011 amendment to the NMFS RPA, NMFS clarified the timing, magnitude, and duration of established flows are intended to provide certain hydrologic features at certain times of year to benefit Central Valley steelhead. Based upon the advice of the Stanislaus Operations Group and the concurrence from NMFS, flows may be implemented with minor modifications to the timing, magnitude, and/or duration, as long as NMFS concurs that the rationale for the shift in timing, magnitude, and/or duration is deemed to be consistent with the intent of the action. This flow schedule is included in the proposed action in the current Biological Opinion (National Marine Fisheries Service 2019).

The flow schedule provided by NMFS in 2011, included the following components:

- Minimum base flows based on Instream Flow Incremental Methodology (Aceituno 1993) to optimize available Central Valley steelhead habitat for adult migration, spawning, and juvenile rearing. These base flows are scaled to water year type as defined by the New Melones water supply parameter, with lowest flows in critically dry years and highest flows in wet years.
- Fall pulse flow to improve in-stream conditions sufficiently to attract Central Valley steelhead to the Stanislaus River.
- Winter instability flows to simulate natural variability in the winter hydrograph and to enhance access to varied rearing habitats.
- Channel forming and maintenance flows in the 3,000 to 5,000 cfs range in above normal and wet years to maintain spawning and rearing habitat quality. These flows are scheduled to occur after March 1 to protect incubating eggs and are intended to work synergistically with providing out-migration flow cues and late spring flows. These flows are high intensity, but limited in duration to avoid potential seepage issues that have been alleged under extended periods of flow greater than 1,500 cfs. These flows provide flow cues downstream for incoming adults, as well as some remedial effect on the low DO conditions that develop in the Stockton Deep Water Ship Channel. In addition to benefiting steelhead, this action also produces ancillary benefits to Essential Fish Habitat for Pacific salmonids (i.e., fall-run Chinook salmon).

Table O-6. Stanislaus River Minimum Fish Flow Schedule During Critically Dry Water Year Types

	Monthly Flow (cfs)											
Date	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1	200	200	200	200	200	200	200	725	150	150	150	150
2	200	200	200	200	200	200	200	725	150	150	150	150
3	200	200	200	400	200	200	200	725	150	150	150	150
4	200	200	200	400	200	200	200	725	150	150	150	150
5	200	200	200	200	400	200	200	725	150	150	150	150
6	200	200	200	200	400	200	200	725	150	150	150	150
7	200	200	200	200	200	200	200	725	150	150	150	150
8	200	200	200	200	200	200	200	725	150	150	150	150
9	200	200	200	200	200	200	200	725	150	150	150	150
10	200	200	200	200	200	200	200	725	150	150	150	150
11	200	200	200	200	200	200	200	725	150	150	150	150
12	200	200	200	200	200	200	200	725	150	150	150	150
13	200	200	200	200	200	200	200	550	150	150	150	150
14	200	200	200	200	200	200	200	450	150	150	150	150
15	500	200	200	200	200	200	350	300	150	150	150	150
16	750	200	200	200	200	200	500	150	150	150	150	150
17	1000	200	200	200	200	200	725	150	150	150	150	150
18	1250	200	200	200	200	200	725	150	150	150	150	150
19	1250	200	200	200	200	200	725	150	150	150	150	150
20	1250	200	200	200	200	200	725	150	150	150	150	150
21	1250	200	200	200	200	200	725	150	150	150	150	150
22	1250	200	200	200	200	200	725	150	150	150	150	150

Date	Monthly Flow (cfs)											
	October	November	December	January	February	March	April	May	June	July	August	September
23	1250	200	200	200	200	200	725	150	150	150	150	150
24	1250	200	200	200	200	200	725	150	150	150	150	150
25	1250	200	200	200	200	200	725	150	150	150	150	150
26	1000	200	200	200	200	200	725	150	150	150	150	150
27	750	200	200	200	200	200	725	150	150	150	150	150
28	500	200	200	200	200	200	725	150	150	150	150	150
29	200	200	200	200	NA	200	725	150	150	150	150	150
30	200	200	200	200	NA	200	725	150	150	150	150	150
31	200	NA	200	200	NA	200	NA	150	NA	150	150	NA

cfs = cubic feet per second; NA = Not Applicable.

Table O-7. Stanislaus River Minimum Fish Flow Schedule During Dry Water Year Types

Date	Monthly Flow (cfs)											
	October	November	December	January	February	March	April	May	June	July	August	September
1	200	200	200	200	200	200	200	1000	200	200	200	200
2	200	200	200	200	200	200	200	1000	200	200	200	200
3	200	200	200	400	200	200	200	1000	200	200	200	200
4	200	200	200	400	200	200	200	1000	200	200	200	200
5	200	200	200	400	400	200	200	1000	200	200	200	200
6	200	200	200	200	400	200	200	1000	200	200	200	200
7	200	200	200	200	400	200	200	1000	200	200	200	200
8	200	200	200	200	200	200	350	1000	200	200	200	200
9	200	200	200	200	200	200	500	1000	200	200	200	200

Date	Monthly Flow (cfs)											
	October	November	December	January	February	March	April	May	June	July	August	September
10	200	200	200	200	200	200	750	1000	200	200	200	200
11	200	200	200	200	200	200	1000	1000	200	200	200	200
12	200	200	200	200	200	200	1000	1000	200	200	200	200
13	200	200	200	200	200	200	1000	1000	200	200	200	200
14	200	200	200	200	200	200	1000	1000	200	200	200	200
15	500	200	200	200	200	200	1000	1000	200	200	200	200
16	750	200	200	200	200	200	1000	800	200	200	200	200
17	1000	200	200	200	200	200	1000	600	200	200	200	200
18	1250	200	200	200	200	200	1000	450	200	200	200	200
19	1250	200	200	200	200	200	1000	300	200	200	200	200
20	1250	200	200	200	200	200	1000	200	200	200	200	200
21	1500	200	200	200	200	200	1000	200	200	200	200	200
22	1500	200	200	200	200	200	1000	200	200	200	200	200
23	1500	200	200	200	200	200	1000	200	200	200	200	200
24	1250	200	200	200	200	200	1000	200	200	200	200	200
25	1250	200	200	200	200	200	1000	200	200	200	200	200
26	1250	200	200	200	200	200	1000	200	200	200	200	200
27	1000	200	200	200	200	200	1000	200	200	200	200	200
28	750	200	200	200	200	200	1000	200	200	200	200	200
29	500	200	200	200	NA	200	1000	200	200	200	200	200
30	200	200	200	200	NA	200	1000	200	200	200	200	200
31	200	NA	200	200	NA	200	NA	200	NA	200	200	NA

cfs = cubic feet per second; NA = Not Applicable.

Table O-8. Stanislaus River Minimum Fish Flow Schedule During Below Normal Water Year Types

	Monthly Flow (cfs)											
Date	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1	250	200	200	200	200	200	400	1500	900	250	250	250
2	250	200	200	200	200	200	750	1500	600	250	250	250
3	250	200	200	400	200	200	1000	1500	600	250	250	250
4	250	200	200	400	200	200	1250	1500	600	250	250	250
5	250	200	200	400	400	200	1500	1500	600	250	250	250
6	250	200	200	400	400	200	1700	1500	600	250	250	250
7	250	200	200	200	400	200	2000	1500	450	250	250	250
8	250	200	200	200	400	200	2000	1500	450	250	250	250
9	250	200	200	200	200	200	2000	1500	450	250	250	250
10	250	200	200	200	200	200	2000	1500	450	250	250	250
11	250	200	200	200	200	200	1500	1500	300	250	250	250
12	250	200	200	200	200	200	1500	1500	300	250	250	250
13	250	200	200	200	200	200	1500	1500	300	250	250	250
14	250	200	200	200	200	200	1500	1250	300	250	250	250
15	500	200	200	200	200	200	1500	1250	250	250	250	250
16	750	200	200	200	200	200	1500	1250	250	250	250	250
17	1000	200	200	200	200	200	1500	1250	250	250	250	250
18	1250	200	200	200	200	200	1500	1250	250	250	250	250
19	1500	200	200	200	200	200	2000	1250	250	250	250	250
20	1500	200	200	200	200	200	2000	1000	250	250	250	250
21	1500	200	200	200	200	200	2000	1000	250	250	250	250
22	1500	200	200	200	200	200	2000	1000	250	250	250	250
23	1500	200	200	200	200	200	1500	1000	250	250	250	250

Date	Monthly Flow (cfs)											
	October	November	December	January	February	March	April	May	June	July	August	September
24	1500	200	200	200	200	200	1500	1000	250	250	250	250
25	1500	200	200	200	200	200	1500	1000	250	250	250	250
26	1500	200	200	200	200	200	1500	1000	250	250	250	250
27	1500	200	200	200	200	200	1500	900	250	250	250	250
28	1250	200	200	200	200	200	1500	900	250	250	250	250
29	1000	200	200	200	NA	200	1500	900	250	250	250	250
30	750	200	200	200	NA	200	1500	900	250	250	250	250
31	500	NA	200	200	NA	200	NA	900	NA	250	250	NA

cfs = cubic feet per second; NA = Not Applicable.

Table O-9. Stanislaus River Minimum Fish Flow Schedule During Wet Water Year Types

Date	Monthly Flow (cfs)											
	October	November	December	January	February	March	April	May	June	July	August	September
1	400	300	300	300	300	600	800	4800	1200	800	400	400
2	400	300	300	300	300	1200	800	4800	1200	500	400	400
3	400	300	300	600	300	2400	1200	4500	1200	500	400	400
4	400	300	300	600	300	5000	2400	4500	1200	500	400	400
5	400	300	300	600	600	5000	5000	4500	1200	500	400	400
6	400	300	300	600	600	5000	5000	2400	1200	500	400	400
7	400	300	300	600	600	5000	5000	1200	1200	400	400	400
8	400	300	300	600	600	4500	4500	800	1200	400	400	400
9	400	300	300	300	600	2400	3500	800	1200	400	400	400
10	400	300	300	300	600	1200	2400	800	1200	400	400	400

Date	Monthly Flow (cfs)											
	October	November	December	January	February	March	April	May	June	July	August	September
11	400	300	300	300	300	800	1200	800	1200	400	400	400
12	400	300	300	300	300	800	800	800	1200	400	400	400
13	400	300	300	300	300	800	800	800	1200	400	400	400
14	400	300	300	300	300	800	800	800	1200	400	400	400
15	500	300	300	300	300	800	800	800	1200	400	400	400
16	750	300	300	300	300	800	800	800	1200	400	400	400
17	1000	300	300	300	300	800	800	800	1200	400	400	400
18	1250	300	300	300	300	800	800	1500	1200	400	400	400
19	1500	300	300	300	300	800	800	1500	1000	400	400	400
20	1500	300	300	300	300	1200	800	1500	1000	400	400	400
21	1500	300	300	300	300	1200	800	2500	1000	400	400	400
22	1500	300	300	300	300	1200	800	2500	1000	400	400	400
23	1500	300	300	300	300	1200	800	2500	1000	400	400	400
24	1500	300	300	300	300	1200	800	2500	1000	400	400	400
25	1500	300	300	300	300	800	800	2500	1000	400	400	400
26	1500	300	300	300	300	800	800	1500	1000	400	400	400
27	1500	300	300	300	300	800	800	1500	1000	400	400	400
28	1250	300	300	300	300	800	800	1500	800	400	400	400
29	1000	300	300	300	NA	800	1200	1500	800	400	400	400
30	750	300	300	300	NA	800	2400	1500	800	400	400	400
31	500	NA	300	300	NA	800	NA	1500	NA	400	400	NA

cfs = cubic feet per second; NA = Not Applicable.

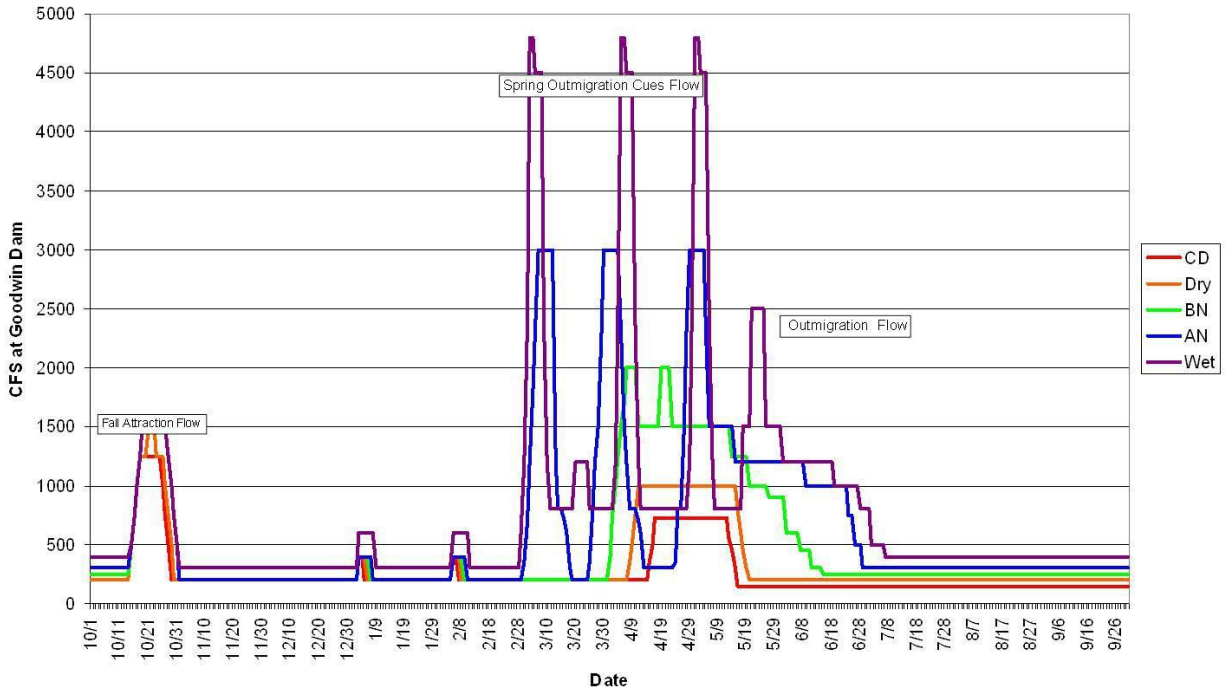


Figure O-6. Depicts Minimum Stanislaus River In-Stream Flow Schedule for Central Valley Steelhead as Measured at Goodwin Dam

Water Temperature

Reclamation manages cold water supply within New Melones Reservoir and make cold water releases from New Melones Reservoir to provide suitable temperatures for all life stages of Central Valley steelhead in the Stanislaus River downstream of Goodwin Dam. The following table provides the criterion and temperature compliance location, duration, and life stage of Central Valley steelhead benefiting from the operation. Reclamation measures temperature compliance based on a 7-day average daily maximum temperature.

The temperature compliance schedule provides an operational framework to minimize temperature-related effects of operations in the reaches of the river most used by Central Valley steelhead on a year-round basis. The temperature criteria for adult Central Valley steelhead migration in the river were included, as it was expected that fall attraction flows would improve downstream temperature conditions necessary for adult migration (National Marine Fisheries Service 2009a).

Table O-10. Criterion and Temperature Compliance Location

Criterion and Temperature Compliance Location	Duration	Steelhead Life Stage Benefit
Temperature below 56°F at Orange Blossom Bridge	October 1–December 31	Adult migration
Temperature below 52°F at Knights Ferry and 57°F at Orange Blossom Bridge	January 1–May 31	Smoltification
Temperature Below 55°F at Orange Blossom Bridge	January 1–May 31	Spawning and incubation
Temperature below 65°F at Orange Blossom Bridge	June 1–September 30	Juvenile rearing

However, in April 2011, more flexibility was provided to the Stanislaus Operation Group to adjust the timing and shape of various pulse flows within the Stanislaus River (National Marine Fisheries Service 2011a).

Dissolved Oxygen

Current operations are required to meet a year-round DO minimum of 7 mg/Lin the Stanislaus River to protect salmon, steelhead, and trout (California Department of Fish and Wildlife 2018). Under existing conditions, it is challenging to maintain DO concentrations above 7 mg/L during drought conditions, and based on recent studies, does not appear to be warranted to protect salmonids in the river (Kennedy and Cannon 2005; Kennedy 2008).

O.1.7.2 Lower Stanislaus River between New Melones Reservoir and San Joaquin River

Fish Evaluated in the Stanislaus River

Steelhead and fall-run Chinook salmon currently occur in the lower Stanislaus River. Historically, spring-run Chinook salmon were believed to be the primary salmon run in the Stanislaus River. Native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River basin, which represents a large portion of their historical range and abundance (National Marine Fisheries Service 2014c). Other non-native anadromous fish species that occur in the lower Stanislaus River include striped bass, American shad, and an unidentified species of lamprey (Stanislaus River Fish Group 2003).

The analysis is focused on the following species:

- Fall-run Chinook salmon, Central Valley ESU
- Steelhead, California Central Valley DPS
- Pacific lamprey
- Western river lamprey
- Hardhead
- American shad

- Striped bass
- Threadfin shad
- Black basses

Fall-run Chinook Salmon, Central Valley ESU

Data collected by fishery consultants, nonprofit organizations, and the CDFW demonstrate the majority of fall-run Chinook salmon adults migrate upstream from late September through December with peak migration from late October through early November. Most Chinook salmon spawning occurs between Riverbank (RM 33) and Goodwin Dam (RM 58.4) (Bureau of Reclamation 2012). Based on redd surveys conducted by FISHBIO Environmental, peak spawning typically occurs in November with roughly 7% of spawning occurring prior to November 1, and 2% prior to October 15. The few redds created during late September and early October are typically in the reach just below Goodwin Dam. By late October, the amount of spawning in downstream locations increases as water temperatures decrease, and the median redd location is typically around Knights Ferry (State Water Resources Control Board 2015).

In 2010, over 20% of the fall-run Chinook salmon observed passing the Stanislaus River weir had adipose fin clips, indicating the presence of a coded wire tag in their snout. Since there is no hatchery on the Stanislaus River and no hatchery releases into this tributary have occurred since 2006, it is apparent that straying from other rivers is occurring (FISHBIO Environmental 2010b).

Rotary screw trap data indicate that about 99% of salmon juveniles migrate out of the Stanislaus River from January through May (Stanislaus River Fish Group 2004). Fry migration generally occurs from January through March, followed by smolt migration from April through May (Bureau of Reclamation 2012). Watry et al. (2012) found that in both 2010 and 2011, peak passage during the pre-smolt period generally corresponded with flow pulses. Zeug et al. (2014) examined 14 years of rotary screw trap data on the lower Stanislaus River and found a strong positive response in survival, the proportion of pre-smolt migrants and the size of smolts when cumulative flow and flow variance were greater. From the data, they concluded that periods of high discharge in combination with high discharge variance are important for successful emigration, as well as migrant size and the maintenance of diverse migration strategies.

Mesick (2001) surmised that when, water exports are high relative to San Joaquin River flows, little, if any, San Joaquin River water reaches San Francisco Bay, where it may be needed to help attract the salmon back to the Stanislaus River. During mid-October from 1987 through 1989, when export rates exceeded 400% of Vernalis flows, Mesick (2001) found that straying rates ranged from 11% to 17%. In contrast, straying rates were estimated to be less than 3% when Delta export rates were less than about 300% of San Joaquin River flow at Vernalis during mid-October.

One of the limiting factors appears to be the high rates of mortality for juveniles migrating through dredged channels in the Stanislaus River and Delta, particularly the Stockton Deep Water Ship Channel (Newcomb and Pierce 2010). Pickard et al. (1982) reported that juvenile survival in the ship channel is highest during flood flows or when a barrier is placed at the head of the Old River that more than doubles the flow in the ship channel. The Stanislaus River Fish Group (2004) noted that escapement is also directly correlated with springtime flows during

outbound migration. However, the cause of the mortality in the ship channel has not been studied. It is possible that mortality results from the combined effects of warm water temperatures, low DO concentrations, ammonia toxicity, and predation.

As discussed earlier, dredging for gravel and gold, regulated flows, and the diking of floodplains for agriculture have substantially limited the availability of spawning and rearing habitat for fall-run Chinook salmon. Reclamation has conducted spawning gravel augmentation to improve spawning and rearing habitats in the reach between Goodwin Dam and Knights Ferry most years since 1999. The dredged areas also contain an abundance of large predatory fish, although the Stanislaus River Fish Group concluded that there is uncertainty about whether predation is a substantial source of mortality for juvenile salmon.

The Stanislaus River Fish Group also concluded that water diversions for urban and agricultural use in all three San Joaquin River tributaries, which reduce flows and potentially result in unsuitably warm water temperatures during spring and fall, affect fall-run Chinook salmon juvenile rearing and adult and juvenile migration in the lower San Joaquin River and Delta.

Steelhead, California Central Valley DPS

Steelhead have been extirpated from their historical range in the San Joaquin River basin but current populations survive in the Stanislaus River in tailwater conditions controlled by dams (National Marine Fisheries Service 2009a). Monitoring has detected a small self-sustaining natural origin population of steelhead in the Stanislaus River and in other streams previously thought to be devoid of steelhead (Stanislaus River Fish Group 2003; McEwan 2001). There is a catch-and-release steelhead fishery in the lower Stanislaus River from January 1 to October 15. Surveys of *O. mykiss* (resident rainbow trout and anadromous steelhead) abundance and distribution conducted annually since 2009 have documented a relatively stable population. River-wide abundance estimates from 2009 to 2014 have averaged just over 20,220 (all life stages combined) and have never been estimated to be less than about 14,000 (2009). The highest densities and abundances of *O. mykiss* are consistently found in Goodwin Canyon. Key factors that may contribute to higher than average abundances in the Stanislaus River (relative to other San Joaquin River tributaries) include high gradient reaches that are typically associated with more fast-water habitats, particularly in Goodwin Canyon (State Water Resources Control Board 2015).

Historically, the distribution of steelhead extended into the headwaters of the Stanislaus River (Yoshiyama et al. 1996). Steelhead currently can migrate more than 58 miles up the Stanislaus River to the base of Goodwin Dam. In the Stanislaus River, there is little data regarding the migration patterns of adult steelhead since adults generally migrate during periods when river flows and turbidity are high, making fish difficult to observe with standard adult monitoring techniques. Stanislaus River video monitoring data indicate that steelhead migrate upstream, through the south Delta and lower San Joaquin River, September through April, and can be found in the rotary screw trap in Oakdale from November through April (Hellmair 2022; Eschenroeder et al. 2022). High Delta export rates relative to San Joaquin River flows at Vernalis, when adults are migrating through the Delta (presumably December through May), may result in adults straying to the Sacramento River basin.

Data on steelhead spawning in the Stanislaus River is limited, but adults appear to spawn primarily from February to April. In 2021, as part of the reasonable and prudent measure to accelerate steelhead monitoring and research in the NMFS (2019) Biological Opinion, the CDFW initiated the Stanislaus River Life Cycle Monitoring Program. Based on the initial redd survey report, spawning appears to start in February and last until April (Kok and Keller 2023). Spawning *O. mykiss* was documented upstream of the Highway 120 bridge in Oakdale, between Goodwin Dam and the Oakdale Recreation Area. Spawning adults require holding and feeding habitat with cover adjacent to suitable spawning habitat. These habitat features are relatively rare in the lower Stanislaus River because of in-river gravel mining and the scouring of gravel from riffles in Goodwin Canyon.

Juvenile steelhead rear in the Stanislaus River for at least one year, and usually two years, before outmigrating to the ocean. As a result, flow, water temperature, and DO concentration in the primary rearing habitat between Goodwin Dam and the Orange Blossom Bridge are critical during summer (Bureau of Reclamation 2012).

Small numbers of steelhead smolts have been captured in rotary screw traps at Caswell Memorial State Park and near Oakdale (CalFish 2023), and data indicate that steelhead outmigrate primarily from February through May. Rotary screw traps are generally not considered efficient at catching fish as large as steelhead smolts, and the number captured is too small to estimate capture efficiency, so no steelhead smolt out-migration population estimate has been calculated. The capture of these fish in downstream migrant traps and the advanced smolting characteristics exhibited by many of the fish indicate that some steelhead/rainbow trout juveniles might migrate to the ocean in spring. However, it is not known whether the parents of these fish were anadromous or fluvial (i.e., migrate within freshwater). Resident populations of steelhead/rainbow trout in large streams are typically fluvial, and migratory juveniles look much like smolts.

Pacific Lamprey

The Pacific lamprey inhabits accessible reaches of the Stanislaus River (Stanislaus River Fish Group 2003). Limited information on Pacific lamprey status in the Stanislaus River exists, but the species has experienced loss of access to historical habitat and apparent population declines throughout California and the Sacramento and San Joaquin River basins (Moyle et al. 2009). Little information is available on factors influencing Pacific lamprey populations in the Stanislaus River, but they are likely affected by many of the same factors as salmon and steelhead because of similarities in life cycles.

Ocean stage adults likely migrate into the Stanislaus River in spring and early summer, where they hold for approximately 1 year before spawning (Hanni et al. 2006). Spawning time in the Stanislaus River is presumably similar to that observed in other rivers, such as the American River (early January to late May, with peak spawning typically in early April; Hannon and Deason 2008). Pacific lamprey ammocoetes are expected to rear in the Stanislaus River for all or part of their 3- to 7-year freshwater residence. Data from rotary screw trapping in the nearby Mokelumne and Tuolumne Rivers suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006). Catches of juvenile Pacific lampreys in trawl surveys of the mainstem San Joaquin River, near the mouth of the Stanislaus River at Mossdale, occurred during winter and spring. Some out-migration from the Stanislaus

River likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006). Significant numbers of lampreys of unknown species and unspecified life stage have been captured during rotary screw trapping on the Stanislaus River at Oakdale (FISHBIO Environmental 2007) and Caswell (Watry et al. 2007). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Pacific Lamprey*.

Western River Lamprey

Western river lamprey have been observed in the Stanislaus River but their overall abundance and distribution is poorly understood. Relative catch of lamprey at the two rotary screw traps, Caswell and Oakdale, is relatively high but, due to difficulties with identification, they are not identified to the species and recorded as lamprey unknown (Parker 2022). River lamprey seem to be primarily associated with the lower portions of large river systems, and most records for California are from the lower Sacramento–San Joaquin system, especially the Stanislaus and Tuolumne Rivers (Moyle et al. 1995; Moyle 2002). Quantitative data on populations are extremely limited, but loss and degradation of historical habitats suggest populations may have declined. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Western River Lamprey*.

Hardhead

The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are a frequent catch in the lower Stanislaus River (Bradbury and Hickey 2019). In other parts of their range, populations have declined or have become increasingly isolated (Moyle 2002). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Hardhead*.

American Shad

American shad migrate up the Stanislaus River to spawn in the late spring and support a sport fishery during that period. American shad have been observed on occasion from June through July at Lovers Leap (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). American shad were found primarily in the faster habitats and were observed in schools of 20 or more (U.S. Fish and Wildlife Service 2002). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *American Shad*.

Threadfin Shad

Threadfin shad were introduced in reservoirs throughout California to provide forage for game fish, with the Sacramento and San Joaquin River Basins introductions starting as early as 1959. From these transplants, they have become established in the Sacramento–San Joaquin River system and the Delta. Juvenile threadfin shad are occasionally captured in the Caswell rotary screw trap during winter and early spring months and individuals are present year-round in New Melones Reservoir. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Threadfin Shad*.

Striped Bass

Striped bass occur in the Stanislaus River, and they support a sport fishery when adult fish migrate upstream to spawn. Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. These adult fish were observed in all habitats (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (U.S. Fish and Wildlife Service 2002).

Black Basses

Three *Micropterus* sp. constitute the group of black basses in California, and include largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species). All three species can be found in the lower Stanislaus River. Bycatch data from juvenile salmonid emigration monitoring at the Caswell Rotary Screw Trap in the lower Stanislaus River captured all three species of black basses, making up approximately 5.5% of all fish documented, and spotted bass being the most common (87%) of the black basses encountered at the screw trap (Day 2022c). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Black Basses*. The effects analysis evaluates potential changes in flow and water temperature from LTO project alternatives, and how those changes may affect habitat and optimal temperature ranges for black basses.

Largemouth bass were introduced in California in 1891 (Dill and Cordone 1997; Moyle 2002) and have since established streams and reservoirs throughout the state.

Largemouth bass first spawn during their second or third spring at about 7 inches in length. Spawning is limited to fresh water (Moyle 2002). The males begin building nests when the water temperature reaches about 60°F (15.6°C). Spawning takes place from April through June, at temperatures up to 75°F (23.9°C). Nests are shallow pits in depths of 3 to 7 feet and are often built next to submerged objects. Females lay their eggs in one or more nests. The eggs hatch in 2 to 5 days and sac fry usually spend 5 to 8 days in or near the nest (Moyle 2002). For the first month or two after hatching, fry feed mainly on zooplankton. YOY bass stay close to shore in schools that swim in the open water. By the time they reach about 2 inches in length, the juveniles feed largely on aquatic insects and fish fry, including other largemouth bass, and after they reach 4 to 5 inches, they prey primarily on fish and crayfish. Largemouth bass are thought to be a major predator of juvenile Chinook salmon and other native fish species in the Delta (Nobriga and Feyrer 2007). In addition to the Delta, they occur in lower riverine habitats such as in the Feather River and American River. Their growth rate is highly variable, depending on genetic background, food availability, inter- and intra-specific competition, temperature regimes, and other environmental factors. Maximum size for the species is approximately 30 inches TL and the maximum age is 16 years (Moyle 2002).

Largemouth bass prefer warm, quiet waters with aquatic vegetation and low turbidity. They are known to tolerate DO levels as low as 1 mg/L (Lee et al. 1980; Moyle 2002). The species thrives in areas with high levels of infestation by nonnative aquatic plants (Brown and Michniuk 2007). Recent studies suggest juvenile and larger largemouth bass abundance is positively correlated with water temperature, whereas juvenile largemouth bass abundance is greatest at intermediate levels of submerged aquatic vegetation but larger fish are widespread even in areas with limited submerged aquatic vegetation (Conrad et al. 2016). A study in the San Joaquin River between the

HOR and Stockton in 2015–2016 found a mean of 333 largemouth bass per km, which were estimated to consume 3 to 5 fall-run Chinook salmon per day per km during the peak of the salmon outmigration period, compared to 0 to 24 salmon consumed per day per km by striped bass (Michel et al. 2018).

Smallmouth bass may have been first introduced in California in the 1870s (Dill and Cordone 1997). Smallmouth bass are most common in large, clear lakes and cool, clear streams with large amounts of cover. In streams they prefer complex habitat with a variety of pools, riffles, runs, rocky bottoms, and overhanging trees, while lake populations concentrate in narrow bays along shores where rocky shelves project under water.

Optimal water temperature differs with age, as adults tend to stay in areas 25°C to 27°C (77°F to 80.6°F), while younger fish prefer areas 29°C to 31°C (84.2°F to 87.8°F), reflecting their shallower water environment. Regardless of age, however, temperatures greater than 35°C (95°F) are metabolically stressful, and temperatures over 38°C (100.4°F) are lethal. Smallmouth bass are also restricted in their habitat choice by the amount of DO in the water. Although they can survive in areas with 1 to 3 mg/L, they require at least 6 mg/L for normal growth rates (University of California, Agriculture and Natural Resources 2019a). Juveniles and populations in crowded lakes may school, but this is rare and the majority are solitary hunters that stalk around some kinds of submerged debris. This localizes populations to such a degree that several reproductively independent groups can exist within a single lake. Foraging occurs throughout the day but is most intense in the evening and the early morning. Crustaceans and aquatic insects make up the majority of a smallmouth bass's diet until it reaches 3 to 5 cm (1.18–1.97 inches) TL, at which point crayfish and fish become more important. By the time an individual reaches 10 to 15 cm (3.94–5.91 inches) TL, these larger food items dominate the diet. Smallmouth bass are opportunistic, however, and insects, amphibians, and small mammals are not uncommon sources of food (University of California, Agriculture and Natural Resources 2019a).

Smallmouth bass reach maturity in their third or fourth spring, at which point they move into shallower water. Spawning begins in May and can continue into June or July. Males construct nests 30 to 60 cm (11.81–23.62 inches) in diameter, preferably in rubble, gravel, or sand 1 meter (3 feet) deep with submerged logs, boulders, and other submerged objects acting as cover. This is only the optimal environment, however, and nests can be found on a variety of substrates varying in depth from 0.5 to 5 meters (1.64–16.4 feet). These nests may be built close together, but they are not colonial and males defend the nests against other males as vigorously as they would against predators. Spawning is initiated by a female repeatedly swimming by a nest, changing colors, and keeping her head down in a mating posture. Eventually the pair circle the nest, with the male nipping at the female and the female occasionally rubbing her abdomen on the nest floor. The pair then settle into the nest and release their eggs and milt simultaneously. Smallmouth bass are mostly monogamous, but the larger fish spawn earlier in the season and may have the opportunity to spawn again. Each female may release 2,000 to 21,000 eggs into her nest. The males guard the embryos and fan water over them to provide more oxygen. After hatching, it takes 1 to 2 weeks before fry become free swimming, and the male still guards them for another 1 to 4 weeks after that until they are too active to be herded. At 2 to 3 cm TL (0.79–1.18 inches), the young disperse to shallow water where high mortality rates are suffered because of predation and high stream flows. Those that survive generally grow to between 6 cm (2.36 inches) and 18 cm (7.09 inches) in their first year, and between 25 cm (9.84 inches) and 41 cm

(16.14 inches) in their fourth, while stream populations grow at a decidedly slower rate. The largest individual on record weighed 4.1 kg (9.04 pounds) (University of California, Agriculture and Natural Resources 2019a). All life stages of smallmouth bass can occur in the freshwater regions of the Delta and lower portions of Central Valley rivers (Moyle 2002; Brown and May 2006; Brown and Michniuk 2007; Seesholtz et al. 2004).

Spotted bass are most common in moderately sized, clear, low-gradient rivers and reservoirs. In streams they spend most of their time hiding in pools, avoiding riffles or backwaters with heavy plant growth. Reservoir populations stay along steep rocky banks toward the upstream end of the reservoir. During the summer they can be found in temperatures between 24°C (75.2°F) and 31°C (87.8°F), and despite a low tolerance for brackish water, they have been found in salinities up to 10 ppt. Juveniles can easily be seen schooling in shallow areas close to shore, but adults are more solitary and spend most of their time 1 meter to 4 meters (3–12 feet) deep or even farther down when temperatures equalize in winter. Like most fish, the spotted bass's diet expands as a fish gets older. Fry eat mostly zooplankton and small insects, and then move on to crustaceans and larger aquatic insects as juveniles. Individuals between 75 mm and 150 mm (2.95–5.9 inches) feed on aquatic insects, fish, crayfish, and terrestrial insects, eventually preferring crayfish (University of California, Agriculture and Natural Resources 2019b).

Maturity is reached in the second or third year and spawning occurs when temperatures reach 15°C to 18°C (59°F to 64.4°F), continuing until temperatures reach 22°C to 23°C (71.6°F to 73.4°F) in early June. Males move to shallow water in March and early April, where they construct nests 40 to 80 cm (31.5 inches) in diameter. Lake nests are built in areas 0.5 to 4.5 meters (1.64–14.76 feet) deep with large rocks and rubble or gravel, while nearly any area with low current can be used in rivers. These nests may be built close together, but spotted bass are not colonial and males defend the nests as vigorously against other males as they would against predators. Spawning is initiated by a female repeatedly swimming by a male's nest, changing colors, and keeping her head down in a mating posture. Eventually the pair circles the nest, with the male nipping at the female and the female occasionally rubbing her abdomen on the nest floor. The pair then settle into the nest and release their eggs and milt simultaneously. Spotted bass are mostly monogamous, but some males may have more than one nest. Each female lays 2,000 to 14,000 eggs per nest. The male tends to and defends the nest for up to 4 weeks until the fry disperse at 30 mm TL (1.18 inches). Growth varies with habitat. Warmwater reservoirs support the highest growth, and cold streams support the slowest. On average, however, individuals reach 65 mm to 170 mm TL (2.56–6.69 inches) in their first year and 245 to 435 mm TL (9.65–17.13 inches) in their fourth. Few live longer than 4 or 5 years, and the largest recorded individual for California was 450 mm TL (17.72 inches) (University of California, Agriculture and Natural Resources 2019b).

O.1.7.3 New Melones Reservoir, Tulloch Reservoir, and Goodwin Dam

The north, middle, and south forks of the Stanislaus River converge upstream of New Melones Reservoir, which is approximately 60 miles upstream from the confluence of the Stanislaus and San Joaquin rivers and is operated by Reclamation. Water from New Melones Reservoir flows into Tulloch Reservoir (Bureau of Reclamation 2010b). Downstream of Tulloch Reservoir, the Stanislaus River flows through the reservoir formed by Goodwin Dam and then approximately 40 miles to the confluence with the San Joaquin River.

Fish in New Melones Reservoir, Tulloch Reservoir, and Above Goodwin Dam

New Melones Reservoir is an artificial environment and does not support a naturally evolved aquatic community. Most of the species in the reservoir were introduced, although a few native species may still be present. From a fisheries perspective, recreational fishing is the most important use of New Melones Reservoir. Fish species in New Melones Reservoir include rainbow trout, brown trout, largemouth bass, sunfish such as black crappie and bluegill, and three species of catfish (Bureau of Reclamation 2010b). rainbow trout, brown trout, and large channel catfish are generally restricted to colder, deeper water during summer, when New Melones Reservoir has two distinct thermal layers of water, although large brown trout and channel catfish are found in shallow water near steep banks at night when they ascend to feed.

Tulloch Reservoir is operated as an afterbay for the New Melones Reservoir and is subject to fluctuating water levels that occur on a daily and seasonal basis. Tulloch Reservoir stratifies weakly during summer and contains a reserve of relatively cold, well-oxygenated water that is released downstream. Tulloch Reservoir supports both warm and cold freshwater habitat. Goodwin Power (2013) reported that the CDFW captured 15 species in Tulloch Reservoir from 1969 through 1998. Five dominant species made up almost 80% of the catch: White catfish (31%), bluegill (20%), Sacramento sucker (11%), smallmouth bass (10%), and black crappie (7%). Of these, only the Sacramento sucker is native. Other native species in the catch were Sacramento hitch, hardhead, Sacramento pikeminnow, and rainbow trout (now stocked). Other nonnative fish found in Tulloch reservoir include largemouth bass and threadfin shad (California Department of Fish and Wildlife 2002b).

Little information exists regarding aquatic resources in the reservoir formed by Goodwin Dam. It is assumed that fish assemblies are similar to those described for Tulloch Reservoir.

O.1.7.4 Aquatic Habitat

Schneider et al. (2003) conducted hydrologic analysis of the Stanislaus River and found that New Melones Dam (built in 1979) and more than 30 smaller dams cumulatively impound 240% of average annual unimpaired runoff. Schneider et al. (2003) concluded that this has reduced winter floods and spring snow melt runoff, and increased summer base flows to supply irrigation demand. As a result, the frequency and extent of overbank flooding has been reduced. Based on historical data and field measurements, Schneider et al. (2003) suggested that the channel had incised approximately 1 to 3 feet since dam construction, and that the discharge needed for overbank flows has approximately doubled.

With respect to the related need for geomorphic flows, Kondolf et al. (2001) estimated bedload mobilization flows in the Stanislaus River to be around 5,000 to 8,000 cfs to mobilize the median particle size of the channel bed material. Flows necessary to mobilize the bed material increased downstream from a minimal 280 cfs where gravel was recently added near Goodwin Dam to about 5,800 cfs at Oakdale Recreation Area (Bureau of Reclamation 2008). Before construction of New Melones Dam, a bed-mobilizing flow of 5,000 to 8,000 cfs was equivalent to a 1.5- to 1.8-year return interval flow. Following construction of the dam, 5,000 cfs represents approximately a 5-year return interval flow, and 8,000 cfs exceeds all flows within the 21-year study period, 1979 to 1999 (maximum flow was 7,350 cfs on January 3, 1997). The probability

of occurrence for a daily average flow exceeding 5,330 cfs (the pre-dam bankfull discharge) is 0.01 per year.

Low DO levels have been measured in the San Joaquin River, in particular in the Deep Water Ship Channel from the Port of Stockton seven miles downstream to Turner Cut (Lee and Jones-Lee 2003). These conditions are the result of increased residence time of water combined with high oxygen demand in the anthropogenically modified channel, which leads to DO depletion, particularly near the sediment-water interface (San Joaquin Tributaries Authority 2012). Despite these conditions, adult salmon and steelhead migration does not appear to be adversely affected (Pyper et al. 2006). However, during the 1960s, Hallock et al. (1970) found that adult radio-tagged Chinook salmon delayed their upstream migration whenever DO concentrations were less than 5 mg/L at Stockton. Water Board D-1422 requires water to be released from New Melones Reservoir to maintain DO standards in the Stanislaus River. It has been shown that low DO conditions in the San Joaquin River during the fall can be ameliorated somewhat through installation of the Head of the Old River Barrier, which increases San Joaquin River flows during the fall (San Joaquin Tributaries Authority 2012). The Port of Stockton has operated an aeration facility to achieve Water Board DO water quality objectives since 2012 reducing the need for the fall HOR Barrier to achieve this purpose.

Spawning and Rearing Habitat

Upstream dams have suppressed channel-forming flows that replenish spawning beds in the Stanislaus River (Kondolf et al. 1996). The physical presence of the dams impedes normal sediment transportation processes. Kondolf et al. (2001) identified levels of sediment depletion at 20,000 cubic yards per year as a result of a variety of factors, including mining and geomorphic processes associated with past and ongoing dam operations. In 2011, 5,000 tons of gravel were placed in Goodwin Canyon downstream of Goodwin Dam, of which about 70% was transported into nearby downstream areas during high flows (Stanislaus Operations Group 2012). In 2021 an additional 7,200 tons of gravel were placed in the Stanislaus River.

Extensive instream gravel mining removed large quantities of spawning habitat from the Stanislaus River (Kondolf et al. 2001). Gravel mining also has resulted in instream mine pits that occur in the primary salmonid spawning areas, including a large, approximately 1-mile-long pit called the Oakdale Recreation Pond. Instream mine pits trap bedload sediment, store large volumes of sand and silt, and pass “sediment-starved” water downstream, where it typically erodes the channel bed and banks to regain its sediment load (Kondolf et al. 2001). Additionally, remnant instream mine pits may serve as areas of high predation on salmonids. Reclamation restores and replenishes spawning gravel and rearing habitat lost from the construction and operation of dams in the Stanislaus River to restore spawning habitat and remediate sediment related loss of geomorphic function, such as channel incision.

Floodplain Habitat

Kondolf et al. (2001) identified that floodplain terraces and point bars inundated before operation of New Melones Reservoir have become fossilized with fine material and thick riparian vegetation that is never rejuvenated by scouring flows. Channel forming flows in the 8,000-cfs range have occurred only twice since New Melones Reservoir began operation in 1979.

Based on historical data and field measurements, Schneider et al. (2003) suggested that the channel incised approximately 1 to 3 feet since dam construction, and that the discharge needed for overbank flows has approximately doubled. Without inundation, the floodplains cannot provide terrestrial food for juvenile salmon or organic matter that helps produce more food within the river. Increased flows required for inundation also have had the effect of further isolating floodplains from the channel, leading to the loss of floodplain habitats.

In 2011, a habitat restoration project to increase spawning habitat also restored 640 feet of remnant side channel habitat, allowing water to flow at the current 1.5year return interval (575 cfs), in addition to three cross channels designed to inundate at higher flows (Stanislaus Operations Group 2011).

O.1.7.5 Fish Passage and Entrainment

Constructed in 1913, Goodwin Dam was probably the first permanent barrier to significantly affect anadromous fish access to upstream habitat in the Stanislaus River. Goodwin Dam had a fishway, but Chinook salmon could seldom pass it, and other salmonids may have been similarly affected. Yoshiyama et al. (1996) estimated that historically Chinook salmon and other salmonids had access to 113 miles of habitat, compared with 58 miles under current conditions.

There are numerous small, unscreened diversions on the lower Stanislaus River (Herren and Kawasaki 2001). The effects of these diversions on fish is not clear; however, in tracking the fate of 49 radio-tagged fish, S.P. Cramer and Associates (1998) did not detect any entrainment at several moderately sized unscreened pumps in the lower Stanislaus River.

O.1.7.6 Predation

Areas of the Stanislaus River, including spawning riffles in the active channel, were mined for gravel and gold primarily from 1940 to 1970. The mined areas consist of long, deep ditches and large ponds that provide habitat for predators, such as striped bass, Sacramento pikeminnow, largemouth bass, and smallmouth bass (Mesick 2002). Studies by S.P. Cramer and Associates (1998) documented predation on juvenile salmonids by striped bass and black basses in the Tuolumne and Stanislaus Rivers. However, in its review of information, the Stanislaus River Fish Group (2004) concluded that the available studies and observations suggest that fish predators in the Stanislaus River may be limited to adult Sacramento pikeminnow and riffle sculpin feeding on newly emerged fry, whereas smallmouth bass, largemouth bass, and possibly American shad probably feed on relatively few parr that remain in the river during late spring and summer when water temperatures are high.

It is possible that predation is high for juveniles rearing in the Stockton Deep Water Ship Channel in the Delta as observed by Pickard et al. (1982). Predation rates on hatchery-reared juveniles and tagged juveniles may be higher than those for naturally produced fish. The Turlock and Modesto Irrigation Districts (1992, 2013), and Tuolumne River Technical Advisory Committee et al. (2006), have documented predation on salmonids by nonnative predatory fishes in the Tuolumne River, primarily in run-of-river gravel mining ponds and dredged areas. Sonke and Fuller (2012) reported the number of juvenile Chinook salmon passing the rotary screw traps at Waterford (2006 to 2012) and Grayson (1995 to 2012) on the Tuolumne River. FISHBIO Environmental (2013a) calculated the potential consumption of juvenile Chinook salmon by predators in the reach between the Waterford and Grayson rotary screw traps in 2012 and found

that consumption of juvenile Chinook salmon in this reach could equal or exceed the number passing the Waterford trap. Based on their consumption calculations and the difference in estimated numbers of juvenile Chinook salmon passing the Waterford and Grayson rotary screw traps, FISHBIO Environmental (2013c) concluded that it is plausible that the majority of juvenile Chinook salmon losses in this reach are due to predation. NMFS (2009) noted that losses on the Stanislaus River have not been similarly quantified, but predation on fall-run Chinook salmon smolts and steelhead by striped bass and largemouth bass has been documented.

O.1.8 San Joaquin River

Since the construction of Friant Dam, significant changes in physical (fluvial geomorphic) processes and substantial reductions in stream flows in the San Joaquin River have occurred, resulting in large-scale alterations to the river channel and associated aquatic, riparian, and floodplain habitats. Throughout the area, there are physical barriers, reaches with poor water quality or no surface flow, and false migration pathways that have reduced habitat connectivity for anadromous and resident native fish (Bureau of Reclamation and California Department of Water Resources 2011). As a result, there has been a general decline in both the abundance and distribution of native fish, with several species extirpated from the system (Moyle 2002).

Moyle (2002) reported that of the 21 native fish species historically present in the San Joaquin River, at least 8 are now uncommon, rare, or extinct. The deep-bodied fish assemblage (e.g., Sacramento splittail, Sacramento blackfish) has been replaced by nonnative species like common carp and catfish.

The San Joaquin River from the Stanislaus River to the Delta is dominated by nonnative species such as largemouth bass, striped bass, black basses, inland silverside, common carp, and several species of sunfish and catfish (Moyle 2002). Anadromous species include fall-run Chinook salmon, steelhead, striped bass, American shad, white sturgeon, and several species of lamprey (Bureau of Reclamation et al. 2003). The fall-run Chinook salmon population is supported in part by hatchery stock in the Merced River. Spawning by anadromous salmonids in the San Joaquin River basin occurs only in the tributaries to the San Joaquin River, including the Merced, Tuolumne, and Stanislaus Rivers (Brown and Moyle 1993). A self sustaining population of spring-run Chinook salmon no longer exist in the San Joaquin River, but are targeted for restoration in this system under Reclamation's San Joaquin River Restoration Program. In early 2015, the program experimentally released juvenile spring-run Chinook salmon into the San Joaquin River near the Merced River. In 2016 and 2017, the program released ancillary adult broodstock (bred specifically for the program) spring-run Chinook salmon into Reach 1 (best holding and spawning habitat in the river) of the restoration area to study if conditions were conducive to natural salmon reproduction (San Joaquin River Restoration Program 2019). The 2017 release produced redds and juveniles and was the first confirmed spawning of spring-run Chinook salmon in the San Joaquin River in more than 65 years (San Joaquin River Restoration Program 2019). In 2019 and 2020, program efforts came to fruition when returning adult spring-run Chinook salmon were captured in fyke nets in the San Joaquin River near the confluence with Bear Creek (San Joaquin River Restoration Program 2021). Genetic sampling, fin clips, and coded wire tags confirmed these adults were program fish which marked the volitional return of spring-run Chinook salmon to the San Joaquin River in more than 65 years (San Joaquin River Restoration Program 2021). The program continues to implement strategies to support a self-

sustaining population of spring-run Chinook salmon. However, due to the nature of this experimental population and uncertainty of future restoration success, spring-run Chinook salmon is not included in the analysis of San Joaquin River fish.

O.1.8.1 Water Operations Management

Flow

Reclamation operates the Friant Division for flood control, irrigation, M&I, and fish and wildlife purposes. Facilities include Friant Dam, Millerton Reservoir, and the Friant-Kern and Madera Canals. Friant Dam provides flood control on the San Joaquin River, provides downstream releases to meet senior water rights requirements above Gravelly Ford, provides restoration flow releases under Title X of Public Law 111-11, and provides conservation storage as well as diversion into Madera and Friant-Kern Canals for water supply. Water is delivered to about a million acres of agricultural land in Fresno, Kern, Madera, and Tulare Counties in the San Joaquin Valley via the Friant-Kern Canal south into Tulare Lake Basin and via the Madera Canal northerly to Madera Irrigation District and Chowchilla Water Districts. A minimum of 5 cfs is required to pass the last holding contract diversion located about 40 miles downstream of Friant Dam near Gravelly Ford.

The San Joaquin River Restoration Program implements the San Joaquin River Restoration Settlement Act in Title X of Public Law 111-11. The USFWS and NMFS issued programmatic biological opinions in 2012 that included project-level consultation for San Joaquin River Restoration Program flow releases. Programmatic ESA coverage is provided for flow releases up to a certain level, recapture of those flows in the lower San Joaquin River and the Delta, and all physical restoration and water management actions listed in the Settlement.

The Stipulation of Settlement of *Natural Resources Defense Council, et al. v. Rogers, et al.* (No. CIV-S-88-1658-LKK/GGH), is based on two goals—the Restoration Goal and the Water Management Goal. To achieve the Restoration Goal, the Settlement calls for, among other things, releases of water from Friant Dam to the confluence of the Merced River (referred to as restoration flows) according to the hydrographs in Settlement Exhibit B. To achieve the Water Management Goal, the Settlement calls for the development and implementation of a plan for recirculation, recapture, reuse, exchange or transfer of restoration flows for the purpose of reducing or avoiding impacts on water deliveries to all of the Friant Contractors caused by restoration flows. Recapture of restoration flows may occur upstream of a capacity restricted reach, or downstream of the Merced River confluence. Recapture can occur at Banta-Carbona, Patterson, or West Stanislaus Irrigation District facilities, or at the Jones or Banks Pumping Plants. Recapture of restoration flows in the Sacramento–San Joaquin Delta under this proposed action would average 65 TAF, ranging from approximately 25 TAF to 78 TAF depending on the water year type.

Water Temperature

Restoration flows are determined through review of the restoration allocation and default flow schedule as determined under the settlement. The flow schedule is determined from a series of pre-set schedules based on water year type and atmospheric conditions. Other factors in consideration include water allocations, unreleased volumes of restoration flows, flow targets set at Gravelly Ford, remaining flexible flow volumes and general operational constraints. Specific

temperature targets were not identified in determining ongoing flow management. Although specific temperatures were not identified, flow schedules based on water year types are created by considering a number of factors including temperature. As a result, prescribed flow schedules indirectly manage for temperature within available resources.

O.1.8.2 Fish Evaluated in the San Joaquin River

The analysis is focused on the following species:

- Fall-run Chinook salmon, Central Valley ESU
- Steelhead, California Central Valley DPS
- Green sturgeon, Southern DPS
- White sturgeon
- Pacific lamprey
- Western river lamprey
- Sacramento splittail
- Hardhead
- Sacramento hitch
- American shad
- Threadfin shad
- Striped bass
- Black basses

Fall-run Chinook Salmon

Fall-run Chinook salmon are present in the San Joaquin River and its major tributaries upstream to and including the Merced River. Spawning and rearing occur in the major tributaries (Merced, Tuolumne, and Stanislaus rivers) downstream of the mainstem dams. Weir counts in the Stanislaus River suggest that adult fall-run Chinook salmon in the San Joaquin River basin typically migrate into the upper rivers from late September to mid-November and spawn shortly thereafter (Pyper et al. 2006; Anderson et al. 2007; FISHBIO Environmental 2010a, 2011).

The San Joaquin River downstream of the Stanislaus River primarily provides upstream passage for adult fall-run Chinook salmon and downstream passage for juveniles and smolts as they out-migrate from the tributary spawning and rearing areas to the Delta and the Pacific Ocean. The juvenile fall-run Chinook salmon out-migration in the San Joaquin River basin typically occurs during winter and spring, primarily from January through May. The out-migration consists primarily of fry in winter and smolts in spring (FISHBIO Environmental 2007, 2013b). Trawl sampling in the lower San Joaquin River from Mossdale to the HOR (the Mossdale Trawl) captures Chinook salmon from February into July, with peak catches generally during April and May (Speegle et al. 2013).

Steelhead, California Central Valley DPS

The current steelhead population in the San Joaquin River is substantially reduced compared with historical levels, although resident rainbow trout occur throughout the major San Joaquin River tributaries. Additionally, small populations of steelhead persist in the lower San Joaquin River and tributaries (e.g., Stanislaus, Tuolumne, and possibly the Merced Rivers) (Zimmerman et al. 2009; McEwan 2001). Steelhead/rainbow trout of anadromous parentage occur at low numbers in all three major San Joaquin River tributaries. These tributaries have a higher percentage of resident rainbow trout compared to the Sacramento River and its tributaries (Zimmerman et al. 2009). Estimates of migrating adults in the San Joaquin River are made from the CDFW angler report cards and suggest that migration starts in July, peaks in December and January, and ends in March (California Department of Fish and Wildlife 2007). Steelhead adults primarily use the mainstem as a migration corridor and no spawning has been reported in the San Joaquin River. Steelhead entering the San Joaquin River basin appear to have a later spawning run, with adult migration peaking December in the San Joaquin River and in September in the Sacramento River.

Presence of steelhead smolts from the San Joaquin River basin is estimated annually by the CDFW based on the Mossdale Trawl (San Joaquin River Group Authority 2011). Mossdale Trawl is located at the upstream margin of the Delta on the San Joaquin River and indicates outmigration timing. The sampling trawls capture steelhead smolts, although usually in small numbers. Between 2002-2021, ad-clipped smolt capture peaked in 2002 (approximately 1 individual) and unclipped smolt capture peaked in 2007 (approximately 33 individuals) (Interagency Ecological Program 2022).

Green Sturgeon, Southern DPS

Green sturgeon are present in the San Joaquin River, but at considerably lower numbers than white sturgeon. From 2007 to 2012, anglers reported catching six green sturgeon in the San Joaquin River (Jackson and Van Eenennaam 2013). Although the reported presence of green sturgeon in the San Joaquin River coincides with the spawning migration period of green sturgeon within the Sacramento River, no evidence of spawning has been detected (Jackson and Van Eenennaam 2013). For general life history information applicable to all Central Valley rivers and tributaries inhabited by green sturgeon, see Section O.1.3.3, *Green Sturgeon, Southern DPS*.

White Sturgeon

Little is known about white sturgeon populations inhabiting the San Joaquin River. Spawning-stage adults generally move into the lower reaches of rivers during winter prior to spawning, then migrate upstream to spawn in response to higher flows (Schaffter 1997; McCabe and Tracy 1994). Based on tag returns from white sturgeon tagged in the Sacramento–San Joaquin Delta and recovered by anglers, Kohlhorst et al. (1991) estimated that over 10 times as many white sturgeon spawn in the Sacramento River as in the San Joaquin River.

CDFW fisheries catch information for the San Joaquin River obtained from fishery report cards (California Department of Fish and Wildlife 2008, 2009b, 2010, 2011, 2012b; California Department of Fish and Wildlife 2013, 2014) documented that anglers upstream of State Route 140 caught from 8 to 25 mature white sturgeon annually during 2007 through 2013. Below State Route 140 downstream to Stockton, anglers caught 2 to 35 mature white sturgeon annually over the same time period; most of the white sturgeon caught were released.

White sturgeon spawning in the San Joaquin River was documented for the first time in 2011 and confirmed in 2012. Viable white sturgeon eggs were collected in 2011 at one sampling location downstream of Laird Park (Gruber et al. 2012) and in 2012 at four sampling locations generally between Laird Park and the Stanislaus River confluence (Jackson and Van Eenennaam 2013). Although the majority of sturgeon likely spawn in the Sacramento River, the results of these surveys confirm that white sturgeon do spawn in the San Joaquin River in both wet- and dry-year conditions and may be an important source of production for the white sturgeon population in the Sacramento–San Joaquin River system. For general life history information applicable to all Central Valley rivers and tributaries inhabited by white sturgeon, see Section O.1.3.3, *White Sturgeon*.

Pacific Lamprey

Data from mid-water trawls in the lower San Joaquin River near Mossdale indicate that Pacific lamprey adults likely migrate into the San Joaquin River in spring and early summer (Hanni et al. 2006). In other large river systems, the initial adult migration from the ocean generally stops in summer, and Pacific lampreys hold until the following winter or spring before undergoing a secondary migration to spawning grounds (Robinson and Bayer 2005; Clemens et al. 2012). Midwater trawl surveys in the San Joaquin River suggest that peak ammocoete out-migration occurs in January and February (Hanni et al. 2006).

Little information is available on factors influencing Pacific lamprey in the San Joaquin River, but they are likely affected by many of the same factors as salmon and steelhead because of parallels in their life cycles. Lack of access to historical spawning habitats because of the mainstem dams and other migration barriers, modification of spawning and rearing habitats, altered hydrology, entrainment by water diversions, and predation by nonnative invasive species such as striped bass all likely influence Pacific lamprey in the San Joaquin River and tributaries. For general life history information applicable to all Central Valley rivers and tributaries inhabited by Pacific lamprey, see Section O.1.3.3, *Pacific Lamprey*.

Western River Lamprey

River lamprey seem to be primarily associated with the lower portions of certain large river systems, and most records for California are from the lower Sacramento–San Joaquin system, especially the Stanislaus and Tuolumne rivers (Moyle et al. 1995; Moyle 2002). Quantitative data on populations are extremely limited, but loss and degradation of historical habitats suggest populations may have declined. River lamprey have been collected in the San Joaquin River at Mossdale, suggesting spawning somewhere in the San Joaquin River Basin. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Western River Lamprey*.

Sacramento Splittail

Historically, Sacramento splittail were widespread in the San Joaquin River and found upstream to Tulare and Buena Vista lakes, where they were harvested by native peoples (Moyle et al. 2004). Today, Sacramento splittail likely ascend the San Joaquin River to Salt Slough during wet years (Baxter 1999). During dry years, Sacramento splittail are uncommon in the San Joaquin River downstream of the Tuolumne River (Moyle et al. 2004). Most spawning takes place in the flood bypasses, along the lower reaches of the Sacramento and San Joaquin Rivers and major tributaries, and lower Cosumnes River and similar areas in the western Delta.

Most juveniles apparently move downstream into the Delta from April to August (Meng and Moyle 1995). The population of Sacramento splittail is largely influenced by extent and period of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Moyle et al. 2004). Other factors that may influence the San Joaquin River portion of the Sacramento splittail population include flood control, entrainment by diversion, recreational fishing, pollutants, and nonnative species (Moyle et al. 2004). For general life history information applicable to all Central Valley rivers and tributaries inhabited by splittail, see Section O.1.3.3, *Sacramento Splittail*.

Hardhead

In the San Joaquin drainage, hardhead are present throughout tributary streams but are largely absent from the valley reaches of the San Joaquin River (Moyle et al. 2015, Moyle and Nichols 1973, Saiki 1984). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Hardhead*.

Sacramento Hitch

Sacramento hitch are now absent from the San Joaquin River and tributaries between Friant Dam and the Merced River (Moyle et al. 2015). Sacramento hitch are occasionally captured in low numbers in the lower sections of the San Joaquin River in the Mossdale trawl monitoring program (Interagency Ecological Program et al. 2022). However, there is only moderate concern for overall species extinction in part due to its fairly secure establishment in some areas (Moyle et al. 2015). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Sacramento Hitch*.

American Shad

Little is known about American shad populations inhabiting the San Joaquin River. American shad may spawn in the San Joaquin River system, but their abundance is unknown. Sport fishing for American shad occurs seasonally in the San Joaquin River. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *American Shad*.

Threadfin Shad

Threadfin shad were introduced in reservoirs throughout California to provide forage for game fish. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most commonly encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Threadfin Shad*.

Striped Bass

Striped bass are regularly found in San Joaquin River tributaries, including in lower mainstem deep pools of the Stanislaus and Tuolumne Rivers (e.g., Anderson et al. 2007). Ainsley et al. (2013) reported that striped bass were collected at two locations between the Head of the Old River and the mouth of the Stanislaus River on the mainstem San Joaquin River in May. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Striped Bass*.

Black Basses

Three *Micropterus spp.* constitute the group of black basses in California, and include largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species). All three species occur in the lower San Joaquin River. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Black Basses*.

O.1.8.3 Aquatic Habitat

Aquatic habitat conditions vary spatially and temporally throughout the lower San Joaquin River because of differences in habitat availability and connectivity, water quantity and quality (including water temperature), and channel morphology.

Downstream of the Stanislaus River confluence, the San Joaquin River is more sinuous than upstream reaches and contains oxbows, side channels, and remnant channels. It conveys the combined flows of the major tributaries, including the Merced, Tuolumne, Stanislaus, and Calaveras rivers. Flood control levees closely border much of the river but are set back in places, creating some off-channel aquatic habitat areas when inundated (Bureau of Reclamation and California Department of Water Resources 2011). The channel gradient in this portion of the San Joaquin River is low, and the lack of gravel or coarser substrate precludes spawning by salmonids.

O.1.8.4 Fish Passage

In the reach of the river downstream of the confluence of the Stanislaus River, fish encounter passage challenges associated with water diversions, and adult salmon migrating upstream from the Delta also may encounter prohibitively high water temperatures that delay migration until temperatures decline (McBain and Trush 2002). Installation of seasonal barriers in the Delta also can impair fish passage.

O.1.8.5 Hatcheries

No hatcheries in the San Joaquin River basin are affected by CVP or SWP operations. The Merced River Hatchery, located on the Merced River, is operated by the CDFW to supplement the fall-run Chinook salmon population. It is not included in the CVP or SWP service areas. As part of the San Joaquin River Restoration Program, the CDFW began operating a conservation hatchery downstream of Friant Dam to produce spring-run Chinook salmon (Bureau of Reclamation and California Department of Water Resources 2010).

O.1.8.6 Predation

Recent studies of predation in the San Joaquin River are limited to the major tributaries, where largemouth bass and smallmouth bass have been identified as the most important predators of juvenile Chinook salmon (McBain and Trush and Stillwater Sciences 2006). Striped bass, channel catfish, and white catfish have also been identified as important salmon predators in the San Joaquin River (Hayes et al. 2017).

O.1.9 Bay-Delta

Ecologically, the Delta consists of three major landscapes and geographic regions: (1) the north Delta freshwater flood basins composed primarily of freshwater inflow from the Sacramento River system; (2) the south Delta distributary channels composed of predominantly San Joaquin River system inflow; and (3) the central Delta tidal islands landscape wherein the Sacramento, San Joaquin, and east side tributary flows converge and tidal influences from San Francisco Bay are greater.

The Yolo Bypass conveys flood flows from the Sacramento Valley, including the Sacramento River, Feather River, American River, Sutter Bypass, and west side streams. When flooded, the bypass provides habitat for a wide variety of fish and aquatic species, including temporary migration corridors and juvenile rearing habitat for anadromous salmonids and other native and anadromous fish.

Suisun Bay and Marsh are ecologically linked with the central Delta, although with different tidal and salinity conditions than found upstream. Suisun Bay and Marsh are the largest expanse of remaining tidal marsh habitat within the greater Bay-Delta ecosystem and include Honker, Suisun, and Grizzly Bays; Montezuma and Suisun Sloughs; and numerous other smaller channels and sloughs. Additionally, waters from the North Delta Arc-Cache Slough complex and mainstem of the Sacramento River flow towards Suisun Bay as outflow from the Delta and provide important habitat for many native aquatic species. The Lindsey-Cache Slough-Liberty Island area is widely regarded as prime real estate for restoration projects in part because of the natural drainage patterns and connections with the Sacramento River (Moyle et al. 2016).

O.1.9.1 Fish and Aquatic Species Evaluated in the Bay-Delta

The Bay-Delta provides unique and, in some places, highly productive habitats for a variety of fish species, including euryhaline and oligohaline resident species and anadromous species. For anadromous species, the Bay-Delta is used by adult fish during upstream migration and by rearing juvenile fish that are feeding and growing as they migrate downstream to the ocean. Conditions in the Bay-Delta influence the abundance and productivity of all fish populations that use the system. Regulatory mechanisms exist, such as D-1641, that regulate Delta outflow controlling instream flows for fish habitat within the Delta and downstream bays. Fish communities currently in the Bay-Delta include a mix of native species, some with low abundance, and a variety of introduced fish, some with high abundance (Matern et al. 2002; Feyrer and Healey 2003; Nobriga et al. 2005; Brown and May 2006; Moyle and Bennett 2008; Grimaldo et al. 2012).

The analysis is focused on the following species:

- Winter-run Chinook salmon, Sacramento River ESU
- Spring-run Chinook salmon, Central Valley ESU
- Fall- and late fall-run Chinook salmon, Central Valley ESU
- Steelhead, California Central Valley DPS
- Green sturgeon, Southern DPS
- White sturgeon
- Delta smelt
- Longfin smelt
- Pacific lamprey
- Sacramento splittail
- Hardhead
- Sacramento hitch
- American shad
- Threadfin shad
- Striped bass
- Black basses (largemouth, smallmouth, spotted)
- Starry flounder

State and federal agencies have been monitoring fish populations in the San Francisco Estuary for decades. Survey methods have included beach seining, midwater trawls, Kodiak trawls, otter trawls, and other methods (Honey et al. 2004) to sample the pelagic fish assemblage throughout the estuary. Plankton nets have also been used to survey the ichthyoplankton community for larval and early postlarval life stages. Three of the most prominent resident pelagic fish captured in the surveys (Delta smelt, longfin smelt, and striped bass) have shown substantial long-term population declines (Kimmerer et al. 2000; Bennett 2005; Rosenfield and Baxter 2007). Reductions in pelagic fish abundance since 2002 have been recognized as a serious water and fish management issue and have become known as the Pelagic Organism Decline (POD) (Sommer et al. 2007a).

In response to the POD, an interagency study team evaluated the potential causes of the decline. Since completion of the first set of studies in late 2005, alternative models were developed based on the available data and at professional judgment of the POD-Modeling Team regarding the extent to which individual drivers were likely to affect each species-life stage. The nine drivers identified (Baxter et al. 2010) were: (1) mismatch of larvae and food; (2) reduced habitat space; (3) adverse water movement/transport; (4) entrainment; (5) toxic effects on fish; (6) toxic effects on fish food items; (7) harmful *Microcystis aeruginosa* blooms; (8) *Potamocorbula amurensis* effects on food availability; and (9) disease and parasites.

The interagency study team found an overall negative trend in habitat quality had occurred for Delta smelt and striped bass (and potentially other fish species) as measured by water quality attributes and midwater trawl catch data since 1967, with Delta smelt and striped bass experiencing the most apparent declines in abundance, distribution, and a related index of environmental quality (Feyrer et al. 2007, 2010). More specifically, the position of X2 and water clarity were observed to be important factors influencing the quality of habitat for these species (Mac Nally et al. 2010). Other factors, such as the introduction of nonnative clam species, temperature, and prey, also contributed to reducing habitat clarity and quality. Pelagic habitat suitability in the San Francisco Estuary has been characterized by changes in X2 (Feyrer et al. 2007, 2010). The abundance of several taxa increases in years when river inflows into the estuary are high and X2 is pushed seaward (Jassby et al. 1995; Kimmerer 2002a, 2002b), implying that the quantity or suitability of estuarine habitat increased when inflows are high. Other analyses by Kimmerer et al. (2009) indicated that neither changes in area nor volume of low salinity water (habitat) account for this relationship, except for striped bass and American shad. This suggested that X2 is indexing other environmental variables or processes rather than simple extent of habitat (Baxter et al. 2010), with such factors potentially including geographic location (Manly et al. 2015).

Winter-run Chinook Salmon, Sacramento River ESU

Winter-run Chinook salmon use the Delta for upstream migration as adults and for downstream migration and rearing as juveniles (del Rosario et al. 2013). Adults migrate through the Delta during winter and into late spring (May/June) enroute to their spawning grounds in the mainstem Sacramento River downstream of Keswick Dam (U.S. Fish and Wildlife Service 2001, 2003b). Adults are believed to primarily use the mainstem Sacramento River for passage through the Delta (National Marine Fisheries Service 2009a). After entry into the Delta, juvenile winter-run Chinook salmon remain and rear in the Delta until they are five to 10 months of age (based on scale analysis) (Fisher 1994; Myers et al. 1998). Although the duration of residence in the Delta is not precisely known, del Rosario et al. (2013) suggested that it can be up to several months. Winter-run Chinook salmon juveniles have been documented in the north Delta (e.g., Sacramento River, Steamboat Slough, Sutter Slough, Miner Slough, Yolo Bypass, and Cache Slough complex); the central Delta (e.g., Georgiana Slough, DCC, Snodgrass Slough, and Mokelumne River complex below Dead Horse Island); south Delta channels, including Old and Middle Rivers (OMR), and the joining waterways between OMRs (e.g., Victoria Canal, Woodward Canal, and Connection Slough); and the western central Delta, including the mainstem channels of the Sacramento and San Joaquin Rivers and Threemile Slough (National Marine Fisheries Service 2009a). Telemetry studies of acoustically tagged, hatchery-origin winter-run juveniles indicated migratory survival of smolts varies by migration route through the Delta (e.g., Sutter Slough, Steamboat Slough, Georgiana Slough) and as a function of both flow and temperature (Hance et al. 2022). Closure of the DCC radial gates is intended to minimize straying adults and migrating juveniles from entering the interior Delta, but some southward net flow still occurs naturally in Georgiana and Threemile sloughs.

Sampling at Chipps Island in the western Delta suggests that winter-run Chinook salmon exit the Delta as early as December and as late as May, with a peak in March (Brandes and McLain 2001; del Rosario et al. 2013). The peak timing of the out-migration of juvenile winter-run Chinook salmon through the Delta is corroborated by recoveries of winter-run-sized juvenile Chinook salmon from the SWP Skinner Delta Fish Protection Facility (Skinner fish facility) and the CVP Tracy Fish Collection Facility (TFCF) in the south Delta (National Marine Fisheries Service 2009a).

Winter-run Chinook salmon have historically been identified using a length-at-date (LAD) method. However, more recently, genetic identification has been more commonly used. Run assignment using the LAD criteria can misidentify run due to overlapping juvenile length distributions. Genetic run assignment can be more accurate compared to LAD run assignment. Harvey et al. (2014) found 49% of genetically identified juveniles at the SWP and CVP fish collection facilities had fork lengths outside their assigned run-specific LAD criteria.

Spring-run Chinook Salmon, Central Valley ESU

The Delta is an important migratory route for all remaining populations of spring-run Chinook salmon. Like all salmonids migrating up through the Delta, adult spring-run Chinook salmon must navigate the many channels and avoid direct sources of mortality (e.g., fishing and predation), but also must minimize exposure to sources of nonlethal stress (e.g., high temperatures) that can contribute to pre-spawn mortality in adult salmonids (Budy et al. 2002; Naughton et al. 2005; Cooke et al. 2006; National Marine Fisheries Service 2009a). Habitat degradation in the Delta caused by factors such as channelization and changes in water quality can present challenges for out-migrating juveniles. Additionally, out-migrating juveniles are subjected to predation and entrainment in the project export facilities and smaller diversions (National Marine Fisheries Service 2009a). Further detail is provided later in this section.

Spring-run Chinook salmon returning to spawn in the Sacramento River system enter the San Francisco Estuary from the ocean in January to late February and move through the Delta prior to entering the Sacramento River. Several populations of spring-run Chinook salmon occur in the Sacramento River basin, but historical populations that occurred in the San Joaquin River and tributaries have been extirpated. The Sacramento River channel is the main spring-run Chinook salmon migration route through the Delta. However, adult spring-run Chinook salmon may stray into the San Joaquin River side of the Delta in response to water from the Sacramento River basin flowing into the interconnecting waterways that join the San Joaquin River channel through the DCC, Georgiana Slough, and Threemile Slough. Closure of the DCC radial gates is intended to minimize straying adults and migrating juveniles from entering the interior Delta, but some southward net flow still occurs naturally in Georgiana and Threemile sloughs.

Juvenile spring-run Chinook salmon show two distinct out-migration patterns in the Central Valley: out-migrating to the Delta and ocean during their first year of life as YOY, or holding over in their natal streams and out-migrating the following fall/winter as yearlings. Peak movement of juvenile spring-run Chinook salmon in the Sacramento River at Knights Landing generally occurs in December, and again in March. However, juveniles also have been observed migrating from November to the end of May (Snider and Titus 1998, 2000b, 2000c, 2000d; Vincik et al. 2006; Roberts 2007).

YOY spring-run Chinook salmon presence in the Delta peaks during April and May, as suggested by the recoveries of Chinook salmon in the CVP and SWP salvage operations and the Chipps Island trawls of a size consistent with the predicted size of spring-run fish at that time of year. However, it is difficult to distinguish the YOY spring-run Chinook salmon out-migration from that of the fall-run due to the similarity in their spawning and emergence times and size. Together, these two runs generate an extended pulse of Chinook salmon smolts out-migrating through the Delta throughout spring, frequently lasting into June. Spring-run Chinook salmon juveniles also overlap spatially with juvenile winter-run Chinook salmon in the Delta (National Marine Fisheries Service 2009a). Typically, juvenile spring-run Chinook salmon are not found in the channels of the eastern side of the Delta or the mainstem of the San Joaquin River upstream of Columbia and Turner Cuts.

Fall-/Late Fall-run Chinook Salmon, Central Valley ESU

Central Valley fall-run and late fall-run Chinook salmon pass through the Delta as adults migrating upstream and juveniles out-migrating downstream. Adult fall-run and late fall-run Chinook salmon migrating through the Delta must navigate the many channels and avoid direct sources of mortality and minimize exposure to sources of nonlethal stress. Additionally, out-migrating juveniles are subject to predation and entrainment in the project export facilities and smaller diversions.

Adult fall-run Chinook salmon migrate through the Delta and into Central Valley rivers from June through December. Adult late fall-run Chinook salmon migrate through the Delta and into the Sacramento River from October through April. Adult Central Valley fall-run and late fall-run Chinook salmon migrating into the Sacramento River and its tributaries primarily use the western and northern portions of the Delta, whereas adults entering the San Joaquin River system to spawn use the western, central, and southern Delta as a migration pathway.

Most fall-run Chinook salmon fry rear in freshwater from December through June, with out-migration as smolts occurring primarily from January through June and peak out-migration . In general, fall-run Chinook salmon fry abundance in the Delta increases following high winter flows. Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. A small number of juvenile fall-run Chinook salmon spend over a year in freshwater and out-migrate as yearling smolts the following November through April. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay (MacFarlane and Norton 2002).

Results of mark-recapture studies conducted using juvenile Chinook salmon released into both the Sacramento and San Joaquin Rivers have shown high mortality during passage downstream through the rivers and Delta (Brandes and McLain 2001; Newman and Rice 2002; Buchanan et al. 2013; Perry et al. 2018). Juvenile salmon migrating from the San Joaquin River generally experience greater mortality than fish out-migrating from the Sacramento River. In years when spring flows are reduced and water temperatures are increased, mortality is typically higher in both rivers. Closing the DCC gates and installation of the HOR Barrier to reduce the movement of juvenile salmon into the south Delta from the Sacramento and San Joaquin Rivers, respectively, may contribute to improved survival of out-migrating juvenile Chinook salmon from these watersheds. Additional engineering solutions have been implemented along the Sacramento River including installation of a bio-acoustic fish fence (BAFF) at Georgiana slough

to reduce diversion of juvenile salmonids into the interior and southern Delta. Perry et al. (2014) identified the BAFF reduced entrainment at Georgiana Slough under varying conditions. Hance et al. (2020) additionally considered fish cross-stream position and also identified when the BAFF was not operating the probability of entrainment, both at night and during the day, was higher than when the BAFF was operating.

Although not directly comparable to these previous coded wire tag studies in the San Joaquin River, Buchanan et al. (2013, 2018) found that survival of acoustically tagged hatchery-origin (Feather River) juvenile Chinook salmon was either not statistically different between routes (2009) or was higher through the south Delta via the Old River route than via the San Joaquin River (2010). Additionally, most fish in the Old River that survived to the end of the Delta had been salvaged from the federal water export facility on the Old River and trucked around the remainder of the Delta (Buchanan et al. 2013; San Joaquin River Group Authority 2013; Buchanan and Skalski 2019). Buchanan et al. (2013) indicated that the differences in their results compared to past coded wire tag studies may reflect that an alternative non-physical barrier was being used during their investigation to examine its ability to keep fish out of the Old River instead of the HOR Barrier, which is a physical barrier that reduces not only the number of fish, but also the majority of flows, from entering the Old River. Nonphysical barriers may deprive smolts routed to the San Joaquin River of the increased flows needed for improved survival and may have created conditions for increased predation at the site (Buchanan et al. 2013). Survival of acoustically tagged, hatchery-origin late fall-run juveniles from the Sacramento River was also observed to vary among migration routes, as fish routed to the interior Delta through either the Georgiana Slough or Delta Cross Channel exhibited lower survival than fish routed through Sutter Slough, Steamboat Slough, or the mainstem Sacramento River (Perry et al. 2018).

Juvenile fall-run and late fall-run Chinook salmon migrating through the Delta toward the Pacific Ocean use the Delta, Suisun Marsh, and the Yolo Bypass for rearing to varying degrees, depending on their life stage (fry versus juvenile), size, river flows, and time of year. Movement of juvenile Chinook salmon in the estuarine environment is driven by the interaction between tidally influenced saltwater intrusion through San Francisco Bay and freshwater outflow from the Sacramento and San Joaquin Rivers (Healey 1991). Fall-run adult otolith analyses indicated approximately 25% of sampled adults in 2006 exhibited juvenile growth in brackish estuarine water (Miller et al. 2010).

In the Delta, tidal and floodplain habitat areas provide important rearing habitat for foraging juvenile salmonids, including fall-run Chinook salmon. Studies have shown that juvenile salmon may spend two to three months rearing in these habitat areas, and losses resulting from land reclamation and levee construction are considered to be major stressors (Williams 2010). The channeled, leveed, and riprapped river reaches and sloughs common in the Delta typically have low habitat diversity and complexity, have low abundance of food organisms, and offer little protection from predation by fish and birds.

Steelhead, California Central Valley DPS

Upstream migrating adult steelhead enter the Sacramento River and San Joaquin River basins through their respective mainstem river channels. Steelhead entering the Mokelumne River system (including dry Creek and the Cosumnes River) and the Calaveras River system to spawn are likely to move up the mainstem San Joaquin River channel before branching off into the channels of their natal rivers, although some may detour through the South Delta waterways and enter the San Joaquin River through the HOR.

Migration timing in the Bay-Delta ranges from July until May, with peaks at both the beginning of the spawning season, as migrants move to their natal streams, and at the end of the season, in May, as some post-spawn kelts emigrate back to the ocean (Moyle 2002; Hallock et al. 1961). Steelhead are iteroparous (can spawn more than once), with post-spawn kelts (typically females) potentially moving back downstream through the Delta after completion of spawning in their natal streams.

Some kelts will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022). Steelhead entering the San Joaquin River basin appear to have a later spawning run, with adult migration peaking December/January in the San Joaquin River and in September in the Sacramento River. During the fall, warm water temperatures in the south Delta waterways and low DO at Stockton have been suggested as potential barriers to upstream migration (National Marine Fisheries Service 2009a). Reduced water temperatures, as well as rainfall runoff and flood control release flows, provide the stimulus to adult steelhead holding in the Delta to move upriver toward their spawning reaches in the San Joaquin River tributaries. No steelhead spawning has been reported in the Bay-Delta.

The San Francisco Estuary is used as a short-term outmigration corridor for juvenile steelhead and while outmigration from the Delta can be estimated based on Chinook salmon monitoring programs, the propensity of rearing in the Delta is currently unknown (Hayes and Kocik 2014; Chapman et al. 2015; Buchanan et al. 2021). It is hypothesized that some rearing habitat may occur in areas with flood bypasses (e.g., Yolo Bypass) (National Marine Fisheries Service 2009a). Outmigrating steelhead smolts enter the Delta primarily from the Sacramento or San Joaquin Rivers. Although steelhead have been routinely documented by the CDFW in trawls at Mossdale since 1988 (San Joaquin River Group Authority 2011), it is unknown whether successful outmigration occurs outside the seasonal installation of the barrier at the HOR (from April 15 to May 15 in most years). Prior to the installation of the HOR Barrier, steelhead smolts exiting the San Joaquin River basin could follow one of two routes to the ocean, either staying in the mainstem San Joaquin River through the central Delta, or entering the HOR and migrating through the south Delta and its associated network of channels and waterways.

Juvenile steelhead can be found in all waterways of the Delta, but particularly in the main channels leading from their natal river systems (National Marine Fisheries Service 2009a). Delta entry is monitored at the Sacramento Beach Seines and Trawl locations. Median passage of juvenile steelhead recovered in the Sacramento Trawls occurs February through May and in combined catch data from Sacramento Beach Seines January through March, but with potential for year-round presence of juveniles. Delta exit is monitored at the Chipps Island Trawl location

and median passage occurs February through May. Chipps Island catch data indicate a difference in the emigration timing between natural origin (i.e., unclipped) and hatchery-reared (i.e., clipped) steelhead smolts from the Sacramento River and eastside tributaries. Hatchery fish are typically recovered at Chipps Island from January through March, with a peak in February and March corresponding to the schedule of hatchery releases of steelhead smolts from the Central Valley hatcheries (Nobriga and Cadrett 2001; Bureau of Reclamation 2008). The timing of unclipped steelhead emigration is more protracted and, based on salvage records at the CVP and SWP fish-collection facilities, emigration occurs over approximately 6 months, with the highest levels of recovery in February through June (Aasen 2011, 2012).

Green Sturgeon, Southern DPS

Adult green sturgeon move through the Delta from February through April, arriving at holding and spawning locations in the upper Sacramento River from April to June (Heublein 2006; Kelly et al. 2007). Following their initial spawning run upriver, adults split into two out migration groups, the "early" out migration group may migrate immediately back downstream through the Delta during May-June, or the "late" out migration group may hold for a few weeks to months in the upper river before moving back downstream during November-January (Vogel 2008; Heublein et al. 2009; Colborne et al. 2022). Radio-tagged adult green sturgeon have been tracked moving downstream past Knights Landing during summer and fall, typically in association with pulses of flow in the river (Heublein et al. 2009; Colborne et al. 2022), similar to behavior exhibited by adult green sturgeon on the Rogue River and Klamath River systems (Erickson et al. 2002; Benson et al. 2007).

Similar to other estuaries along the west coast of North America, adult and subadult green sturgeon frequently congregate in the San Francisco Estuary during summer and fall (Lindley et al. 2008). Specifically, adults and subadults may reside for extended periods in the central Delta as well as in Suisun and San Pablo Bays, presumably for feeding, because bays and estuaries are preferred feeding habitat rich in benthic invertebrates (e.g., amphipods, bivalves, and insect larvae). In part because of their bottom-oriented feeding habits, sturgeon are at risk of harmful accumulations of toxic pollutants in their tissues, especially pesticides such as pyrethroids and heavy metals such as selenium and mercury (Israel and Klimley 2008; Stewart et al. 2004).

Juvenile green sturgeon are periodically (although rarely) collected from the lower San Joaquin River at south Delta water diversion facilities and other sites (National Marine Fisheries Service 2009b; Aasen 2011, 2012). Green sturgeon are salvaged from the south Delta Project diversion facilities and are generally juveniles greater than 10 months but less than three years old (Bureau of Reclamation 2008). NMFS suggested that the high percentage of San Joaquin River flows contributing to the TFCF could mean that some entrained green sturgeon originated in the San Joaquin River basin (70 FR 17386). Anglers have reported catching a few green sturgeon in recent years in the San Joaquin River (California Department of Fish and Wildlife 2012b).

After hatching, larvae and juveniles migrate downstream toward the Delta. Juveniles are believed to use the Delta for rearing for the first one to three years of their lives before moving out to the ocean and are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, especially within the central Delta and Suisun Bay/Marsh. Project operations at the DCC have the potential to reroute green sturgeon as they out-migrate through the lower Sacramento River to the Delta (Israel and Klimley 2008; Vogel 2011a). When the DCC

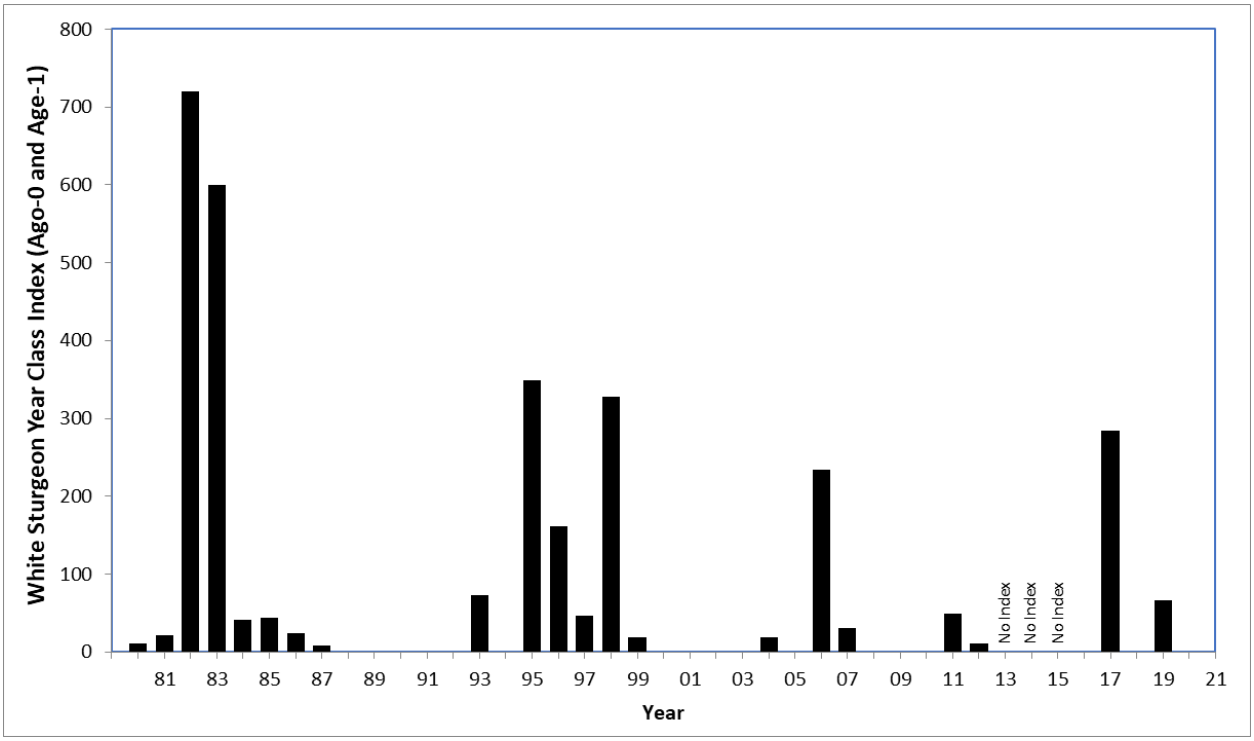
is open, there is no passage delay for adults, but juveniles could be diverted from the Sacramento River into the interior Delta. This has been shown to reduce the survival of juvenile Chinook salmon (Brandes and McLain 2001; Newman and Brandes 2010; Perry et al. 2012), but it is unknown whether it has similar effects on green sturgeon.

Salinity tolerance increases with increasing age and size (McEnroe and Cech 1985), though it is hypothesized that changes in salinity may influence the distribution of juvenile green sturgeon (Heublein et al. 2017a). Juveniles have been found to display a preference for seawater (Poletto et al. 2013). Exposure of young juveniles (<170 days post-hatch) to brackish water can negatively impact growth and survival; growth effects are shown occur at salinities > 10 ppt, and survival effects occur at 20-30 ppt (Allen et al. 2011; Allen and Cech 2007). However, juvenile green sturgeon have a broad tolerance for salinity and are strong enough swimmers to move to acceptable habitat if needed.

Survival during early life history stages may be adversely affected by insufficient flows, lack of rearing habitat, predation, warm water temperatures, decreased DO, chemical toxicants in the water, and entrainment at diversions (Cech et al. 1984; Israel et al. 2008). The direct impact of bioaccumulation of contaminants on the health, survival, and reproductive success of green sturgeon is unknown. Historical habitats, including shallow intertidal feeding habitats, have been lost in the Delta because of channelization. Over-exploitation by recreational fishing and poaching also likely has been an important factor adversely affecting numbers of adult sturgeon (Moyle 2002), although regulations were implemented in 2007 by the CDFW to reduce harvest and there is no legal harvest of green sturgeon due to their ESA listing status. There are substantial passage problems for green sturgeon, such as the Deep Water Ship Channel (National Marine Fisheries Service 2018a), although actions have recently been taken in the Yolo Bypass to improve upstream and downstream sturgeon passage at Fremont Weir.

White Sturgeon

On November 29, 2003, white sturgeon was petitioned for listing as threatened under the federal ESA (San Francisco Baykeeper et al. 2023). Within California, white sturgeon are believed to be most abundant within the Bay-Delta region (Moyle 2002). Both non-spawning adults and juveniles can be found throughout the Delta year-round (Radtke 1966; Kohlhorst et al. 1991; Moyle 2002; California Department of Water Resources et al. 2013). When not undergoing spawning or ocean migrations, adults and subadults are usually most abundant in brackish portions of the Bay-Delta (Kohlhorst et al. 1991). The population status of white sturgeon in the Delta is unclear, but it is not presently listed. Overall, information on trends in adults and juveniles suggests that numbers are declining (Moyle 2002; National Marine Fisheries Service 2009a). Figure O-7 shows the white sturgeon combined age 0 and age 1 year-class index from 1980 through 2020 based on trawl data collected for the San Francisco Bay Study which began in 1980 (California Department of Fish and Wildlife 2022a). The index data suggests year class numbers for these two cohorts has been highly variable since 1980 with a general decrease since the 1990s.



Source: California Department of Fish and Wildlife San Francisco Bay Study – Otter Trawl Data, Interagency Ecological Program.

Figure O-7. White Sturgeon Year Class Index Through Time, 1980–2020

The Delta population of white sturgeon spawns mainly in the Sacramento and Feather rivers, with occasional spawning in the San Joaquin River (Moyle 2002; Jackson 2013). Spawning-stage adults generally move into the lower reaches of rivers during winter prior to spawning and migrate upstream in response to higher flows to spawn from February to early June (McCabe and Tracy 1994; Schaffter 1997). White sturgeon typically spawn in deep pools or runs over a variety of substrates including sand, gravel, cobble, or bedrock (Beccio 2022). Once they broadcast spawn into the water column, the eggs become adhesive and readily stick to the substrate.

After absorbing yolk sacs and initiating feeding, YOY white sturgeon make an active downstream migration that disperses them widely to rearing habitat throughout the lower rivers and the Delta (McCabe and Tracy 1994). White sturgeon larvae have been observed to be flushed farther downstream in the Delta and Suisun Bay in high outflow years, but are restricted to more interior locations in low outflow years (Stevens and Miller 1970).

Salinity tolerance increases with increasing age and size (McEnroe and Cech 1985), allowing white sturgeon to access a broader range of habitat in the San Francisco Estuary (Israel et al. 2008). During dry years, white sturgeon have been observed following brackish waters farther upstream, while the opposite occurs in wet years (Kohlhorst et al. 1991). Adult white sturgeon tend to concentrate in deeper areas and tidal channels with soft bottoms, especially during low tides, and typically move into intertidal or shallow subtidal areas to feed during high tides (Moyle 2002). These shallow water habitats provide opportunities for feeding on benthic

organisms, such as opossum shrimp, amphipods, and even invasive overbite clams, and small fish (Israel et al. 2008; Kogut 2008). White sturgeon also have been found in tidal habitats of medium sized tributary streams to the San Francisco Estuary, such as Coyote Creek and Guadalupe River in the south bay and Napa and Petaluma Rivers and Sonoma Creek in the north bay (Leidy 2007).

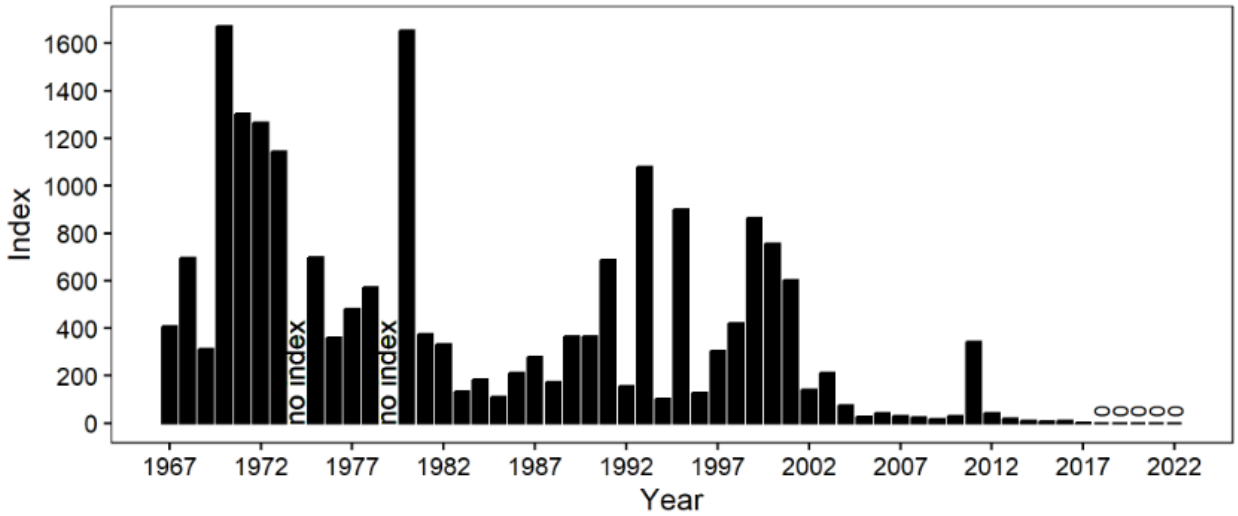
Numerous factors likely affect the white sturgeon population in the Delta, similar to those for green sturgeon. Survival during early life history stages may be adversely affected by insufficient flows, lack of rearing habitat, predation, warm water temperatures, decreased DO, chemical toxicants in the water, and entrainment at diversions (Cech et al. 1984; Israel et al. 2008). Historical habitats, including shallow intertidal feeding habitats, have been lost in the Delta because of channelization. Over-exploitation by recreational fishing and poaching also likely has been an important factor adversely affecting numbers of adult sturgeon (Moyle 2002), sturgeon fisheries in California have been closed multiple times due to overharvest, and regulations were implemented in 2007 and again in 2023 by the CDFW to reduce harvest. Like green sturgeon, there are substantial passage problems for white sturgeon such as the Fremont Weir (Sommer et al. 2014).

Delta Smelt

Delta smelt (*Hypomesus transpacificus*) was listed as a threatened species under the California Endangered Species Act (CESA) in 1993. An emergency petition was filed in February 2007 with the California Fish and Game Commission to elevate the status of Delta smelt from threatened to endangered under CESA (The Bay Institute et al. 2007). On March 4, 2009, the California Fish and Game Commission elevated the status of Delta smelt to endangered under CESA. A 12-month finding on a petition to reclassify the delta smelt as an endangered species was completed by the California Department of Fish and Wildlife (CDFW) on April 7, 2010. After reviewing all available scientific and commercial information, the U.S. Fish and Wildlife Service (USFWS) determined that reclassifying the Delta smelt from threatened to endangered was warranted but was precluded by other higher priority listing actions (U.S. Fish and Wildlife Service 2010).

Delta smelt are endemic to the Bay-Delta (Moyle et al. 1992; Bennett 2005). Declines in the Delta smelt population led to their listing under the ESA as threatened in 1993 (U.S. Fish and Wildlife Service 2008). Delta smelt are one of four pelagic fish species (including longfin smelt, threadfin shad, and juvenile striped bass) documented to be in decline based on fall midwater trawl abundance indices (Sommer et al. 2007b), referred to as the Pelagic Organism Decline (POD). The causes of the declines have been extensively studied and are thought to include a combination of factors, such as decreased habitat quantity and quality, increased mortality rates, and reduced food availability (Feyrer et al. 2007; Sommer et al. 2007b; Moyle and Bennett 2008; Baxter et al. 2010; Mac Nally et al. 2010; Maunder and Deriso 2011; Rose et al. 2013a, 2013b; Sommer and Mejia 2013). Two statistical analyses that used similar data but different statistical methods (Mac Nally et al. 2010; Thomson et al. 2010), examined the dynamics of the four fish species. Both analyses identified several covariates that were related to abundance of the fish, but they could not resolve the cause of the recent declines. The analysis of model results and data for 1995 to 2005 conducted by Rose et al. (2013a) indicated that it has been difficult to ascribe the Delta smelt's decline to a single cause, either over the long term or as part of the 2002 decline.

Delta smelt abundance has continued to decline over the past few years across numerous surveys conducted by the Interagency Ecological Program. Figure O-8 presents the Fall Midwater Trawl Survey abundance indices for Delta smelt from 1967 to 2022 (California Department of Fish and Wildlife 2022b). No Delta smelt were collected in this survey from 2018 through 2022; the Delta smelt index for each of these years was 0, making the index values for this this period the lowest in Fall Midwater Trawl Survey history (California Department of Fish and Wildlife 2022b). Delta smelt abundance estimates from the spring Kodiak trawl and summer townet surveys were also very low from 2018 through 2022. The 20-mm survey index values for 2018, 2020, and 2022 were unable to be calculated due to low catch (California Department of Fish and Wildlife 2023h), and were very low for 2019 (0.1) and 2021 (0). Recently, beginning in the winter of 2021 Delta smelt supplementation efforts have experimentally released captive raised adult Delta smelt into the Delta and will continue in the future (U.S. Fish and Wildlife Service 2021).



Source: California Department of Fish and Wildlife 2022b.

Figure O-8. Fall Midwater Trawl Annual Abundance Indices for Delta Smelt, 1967–2022

Studies conducted to synthesize available information about Delta smelt indicate that Delta smelt have been documented throughout their geographic range during much of the year (Merz et al. 2011; Sommer and Mejia 2013; Brown et al. 2014). Studies indicate that in fall, prior to spawning, Delta smelt tend to remain in the low-salinity zone (Sommer et al. 2011), though they can be found in the lower San Joaquin River, Suisun and San Pablo bays, the Sacramento River and San Joaquin River confluence, Cache Slough, and the lower Sacramento River (Murphy and Hamilton 2013). By spring, they move upstream to freshwater areas of the Delta region, including the Sacramento River and San Joaquin River confluence, the upper Sacramento River, and Cache Slough as well as into Suisun Marsh and the Napa River (Brown et al. 2014; Murphy and Hamilton 2013). There is also a freshwater resident and brackish water resident life history type (Bush 2017; Hobbs et al. 2019) with the freshwater type occurring primarily in the Cache Slough region year-round (Sommer et al. 2011). Both types comprised only a smaller portion of the population studied (12% for the freshwater type and 7% for the brackish water type), the migratory phenotype was most of the population (81%) for fish caught from Sept. – May of 2011

to 2012 (Hobbs et al. 2019). Changing environmental conditions, such as water year type or temperature, may favor different life history phenotypes which may change the proportion of life history types (Cavole et al. 2023; Lewis et al. 2021).

During winter, adult Delta smelt initiate upstream spawning migration in association with "first flush" flow events (Sommer et al. 2011). Others report this seasonal change as a multi-directional and more circumscribed dispersal movement to freshwater areas throughout the Delta region (Murphy and Hamilton 2013). Local and regional changes in adult Delta smelt densities likely include multiple factors, including tide cycle, spawning habitat, and water clarity (Polansky et al. 2018). Adult Delta smelt employ "tidal surfing" to move upstream; On ebb tides, Delta smelt aggregate near frontal zones at the shoal-channel interface moving laterally into the shoals and into the lower half of the water column to minimize advection downstream; on flood tides they move back into the channel and are more evenly distributed through the water column to maintain position or move upriver Feyrer et al. (2013); Bennett and Burau (2015). Turbidity gradients could also be involved in the lateral positioning of Delta smelt within the channels, but large-scale turbidity pulses through the system may not be necessary to trigger upriver migrations of Delta smelt if they are already occupying sufficiently turbid water (Independent Review Panel 2011). After arriving in freshwater staging habitats, adult Delta smelt hold until spawning commences during favorable water temperatures in the late winter-spring (Bennett 2005; Grimaldo et al. 2009; Sommer et al. 2011). Delta smelt spawn over a wide area throughout much of the Delta, including some areas downstream and upstream as conditions allow. Spawning has not been observed in the wild (Moyle et al. 2016). The nonpelagic habitats used by larval Delta smelt before they move into the pelagic areas also are not known (Swanson et al. 1998; Sommer et al. 2011). Larval delta smelt have been found in river channels, along marsh edges, and shallow open water habitats (Grimaldo et al. 2004). Although the specific substrates or habitats used for spawning by Delta smelt are not known, spawning habitat preferences of closely related species (Bennett 2005) suggest that spawning may occur in shallow areas over sandy substrates. Tsai et al. (2022) studied Delta smelt spawning in a laboratory setting and found no difference in spawning behavior, frequency or egg fertilization success when conducted on sand, gravel or acrylic substrates.

During and after larval rearing in freshwater, many young Delta smelt move with river and tidal currents to remain in favorable rearing habitats, often moving into low salinity (< 6 psu) areas to avoid seasonally warm and highly transparent waters that typify many areas in the central Delta (Nobriga et al. 2008). They suggest that this migration strategy can minimize the energy spent swimming against strong river and tidal currents, as well as predation risks by remaining in turbid water.

The distribution of juvenile Delta smelt rearing is correlated with salinity, particularly the position of the low salinity zone, and other habitat attributes. In addition to salinity rearing distribution and habitat suitability have been shown to be influenced by abiotic and biotic factors including outflow (estimated using X2), temperature, turbidity, body size, fish competitors and predators (Bennett 2005; Feyrer et al. 2007, 2010; Hendrix et al. 2023; Kimmerer et al. 2009; Sommer and Mejia 2013). Delta smelt also rear in upstream areas such as the Cache Slough complex and Sacramento Deep Water Ship Channel, depending on habitat conditions (Sommer and Mejia 2013).

The geographical position of the low salinity zone is frequently indexed by X2, which varies primarily as a function of freshwater outflow; thus, X2 typically lies farther east in summer and fall during low outflow conditions and drier water years and farther west during high outflow conditions (Jassby et al. 1995). Higher outflow causes the low salinity zone to more frequently overlap with the Suisun Bay/Marsh region, which is broader and shallower and typically has greater turbidity than the mainstem Sacramento and San Joaquin rivers. Kimmerer et al. (2013) found low salinity zone area and volume was greatest when X2 was in San Pablo Bay, second highest when in Suisun Bay and lowest in the Carquinez Strait and the Delta. The overlap of the low salinity zone with the Suisun Bay/Marsh, based on X2, results in a dramatic increase in habitat suitability (Feyrer et al. 2010); however, Manly et al. 2015 questioned the use by Feyrer et al. (2010) of outflow and X2 location as an indicator of Delta smelt habitat because other, regional factors may be influencing survival such as food availability or bathymetry. Polanksy et al. (2020) found that the location of X2 during the previous fall influenced larval Delta smelt recruitment and that inflow influenced summer juvenile survival. However, juvenile and sub-adult survival were influenced by other factors, including turbidity, temperature, localized hydrodynamics in the South Delta, and predators.

In addition to salinity, turbidity is an important factor associated with habitat use; Delta smelt show a strong preference for higher turbidity water (Feyrer et al. 2007, 2010; Sommer and Mejia 2013), and turbidity may be a key habitat feature and cue initiating the Delta smelt spawning migration (Bennett and Burau 2015; Grimaldo et al. 2009). Turbidity has decreased in recent decades within the Delta (Kimmerer 2004; Schoellhamer 2011), which has likely contributed to declines in environmental quality of Delta smelt habitat (Feyrer et al. 2007, 2010). Higher turbidities are believed to allow Delta smelt to hide from open-water predators, such as striped bass and inland silverside (Gregory and Levings 1998; Nobriga et al. 2005; Schreier et al. 2016), and contribute to feeding success (Lindberg et al. 2000; Hasenbein et al. 2013; Hasenbein et al. 2016; Interagency Ecological Program Management, Analysis, and Synthesis Team 2015).

Water temperature is another important environmental factor that affects Delta smelt habitat and population dynamics (Sommer and Mejia 2013). A longer period of optimal water temperatures in cooler years increases the number of spawning events and cohorts produced (Bennett 2005). During rearing, summer water temperatures also have been shown to be an important predictor of Delta smelt occurrence, based on multi-decadal analyses of summer tow net survey data (Nobriga et al. 2008).

The quality and availability of food also have important effects on the abundance and distribution of Delta smelt (Sommer and Mejia 2013; Kimmerer 2008). Delta smelt feed primarily on zooplankton (Slater and Baxter 2014; Slater et al. 2019) and occasionally on insect larvae and larval fish (Moyle 2002; Hammock et al. 2019). Nobriga (2002) showed that Delta smelt larvae with food in their guts typically co-occurred with higher calanoid copepod densities. Food quality, availability and timing have varied substantially, largely because of the history of nonnative species introduction into the San Francisco Estuary (Baxter et al. 2008; Winder and Jassby 2011; Merz et al. 2016). The decline of zooplankton in the western Delta has been hypothesized to be related to several factors, including increased ammonium concentrations from wastewater effluent and agricultural runoff (Wilkerson et al. 2006; Dugdale et al. 2007; Miller et al. 2012; Glibert 2010; Glibert et al. 2011, 2014) and introduction of the invasive clam *Potamocorbula amurensis* which have drastically reduced phytoplankton available as prey for

zooplankton in addition to predating on copepod nauplii (Kayfetz and Kimmerer 2017; Hammock et al. 2019).

In 2011 and 2012, an unanticipated change in water management operations resulted in higher than normal flows in the Yolo Bypass. These events temporarily resulted in a fall pulse flow in the Yolo Bypass that increased the volume of flow by more than 300% to 900% (Frantzich 2014). Concurrently, a substantial increase in nutrients, phytoplankton, and zooplankton was observed in the Yolo Bypass and Cache Slough. In 2013, the fall pulse flow of rice drainage water did not occur in the Yolo Bypass, and nutrient concentrations did not increase. In 2016, a flow pulse using water from the Cache Slough Complex again led to increased nutrients, phytoplankton biomass and zooplankton density (Frantzich et al. 2021). These nutrient inputs, when they occur, and corresponding increases in phytoplankton and zooplankton production, could contribute to improved foraging opportunities for Delta smelt, though the source of water for the flow pulse may lead to differential response, as well as differing impacts from pesticides (Orlando et al. 2020).

In August 2018, a targeted flow pulse was directed into Suisun Marsh through operation of the Suisun Marsh Salinity Control Gate to enhance habitat for juvenile Delta smelt rearing. The additional flows increased low salinity habitat into more turbid regions with higher phytoplankton biomass but had no substantial effect on zooplankton abundance (Sommer et al. 2020). More Delta smelt were caught during the flow pulse than before and after the flow action but catch of Delta smelt was extremely rare in 2018 leading to the investigators being unable to conclude if the action had any population wide benefits.

Another flow action, the Fall X2 action, released a flow pulse to move and maintain X2 further west to increase habitat available for Delta smelt in Suisun Bay during the fall season. This action occurred in 2017, 2019, and 2023 and is hypothesized to benefit Delta smelt based on research during the wet year of 2011 when a significant increase of Delta smelt was observed (Brown et al. 2014). Lee et al. (2023) found some physical characteristics (such as turbidity) changed during action years, the zooplankton community in Suisun Bay resembled more upstream, freshwater regions, and zooplankton abundance increased in the target regions of Suisun Bay and Suisun Marsh, mainly due to increased presence of *Pseudodiaptomus forbesi*, a key prey item of Delta smelt (Slater and Baxter 2014; Slater et al. 2019). The increase was likely due to subsidies of zooplankton from upstream where *P. forbesi* is more abundant (Hassrick et al. 2023). Mortality of *P. forbesi* in Suisun Bay is very high due to predation by *P. amurensis* and would not exist in the region without freshwater subsidies (Kimmerer et al. 2018). However, during these two years when the action took place, there was no observable increase in Delta smelt abundance, possibly due to high water temperatures during the spring season leading to depressed recruitment and survival of larval fish (Flow Alteration Management Analysis and Synthesis Team 2020). Analysis by Hendrix et al. (2023), found the inclusion of X2 position in occupancy models was not supported, however salinity was a consistent predictor of occupancy (the probability of subregional occupancy was low above 5.6 PSS). Additionally, Smith et al. (2021) suggested that efforts to enhance habitat and prey would likely have a greater potential to positively impact the population earlier in the summer.

Results in prior years indicate that entrainment and salvage-related mortality of Delta smelt associated with water pumping and CVP/SWP exports from the Delta occur primarily from December to July (Kimmerer 2008; Grimaldo et al. 2009; Baxter et al. 2010, Grimaldo et al. 2021). Entrainment occurs when migrating and spawning adult Delta smelt and their larvae overlap in time and space with reverse (southward, or upstream) flows in the Old and Middle River channels (Kimmerer 2008; Grimaldo et al. 2009; Baxter et al. 2010). Turbidity also plays a role in entrainment risk of subadult and adult Delta smelt (Grimaldo et al. 2021). A modeling analysis by Smith et al. (2021) found proportional losses due to entrainment when water clarity was low and Old and Middle River channel flows were reversed. Positive channel flow and high-water clarity resulted in reduced entrainment risk. Historically, fewer adult fish were entrained during wet water years compared to dry and below normal years however fewer adult fish were entrained after 2008, likely due to a combination of changes to operations and the continued decline of the Delta smelt population. Under the 2020 Record of Decision, turbidity is used as an environmental surrogate for changes to Old and Middle River flow exports as part of various actions meant to prevent entrainment of adult and larval Delta smelt including the First Flush Action. Entrainment can also lead to the routing of fish into lower quality habitat, Castillo et al. (2012) found high rates of pre-screen losses of tagged Delta smelt likely due to predation.

In January 2015, the Interagency Ecological Program Management Analysis and Synthesis Team published a report to provide an assessment and conceptual model of factors affecting Delta smelt throughout its life cycle (Interagency Ecological Program Management, Analysis, and Synthesis Team 2015). One focus of the report was an evaluation of a notable increase in abundance of all Delta smelt life stages in 2011, which indicated that the Delta smelt population could potentially rebound when conditions are favorable for spawning, growth, and survival.

The Interagency Ecological Program Management Analysis and Synthesis Team's updated conceptual model described the habitat conditions and ecosystem drivers affecting each Delta smelt life stage, across seasons and how the seasonal effects contributed to the annual success of the species (Interagency Ecological Program Management, Analysis, and Synthesis Team 2015, Baxter et al. 2015). The conclusions of the report highlighted some key hypotheses relating outflow to Delta smelt habitat and survival, using 2011 as the example year in relation to another prior wet year (2006) and two drier years (2005 and 2010). In summary, the report concluded that Delta smelt likely benefitted from the higher outflow and cooler temperatures in winter and spring 2010 and 2011 resulting in: (1) reduced adult and larval entrainment risk; (2) improved spring and early summer habitat quality and food availability for adults through juveniles; and (3) favorable subadult habitat conditions in fall to winter 2010, due to the position of the low salinity zone near Suisun Bay. As discussed above, more recent analyses testing some of these hypothesized relationships have not found clear support.

Longfin Smelt, Bay-Delta DPS

Longfin smelt, San Francisco Bay/Sacramento–San Joaquin Delta (Bay-Delta) DPS is listed as an endangered species under the ESA (89 Fed. Reg. 61029 (July 30, 2024)). The USFWS proposed to list longfin smelt as an endangered species on October 7, 2022 (87 Fed. Reg. 60957 (Oct. 7, 2022)).

Longfin smelt populations occur along the Pacific Coast of North America, and the San Francisco Estuary represents the southernmost population. Longfin smelt generally occur in the Delta; Suisun, San Pablo, and San Francisco Bays; and the Gulf of the Farallones, just outside San Francisco Bay. Actions that benefit Delta smelt, salmonids, and sturgeon, including increasing Delta outflow, have the potential to benefit other fish, including longfin smelt, given their similar habitat requirements and trophic feeding levels.

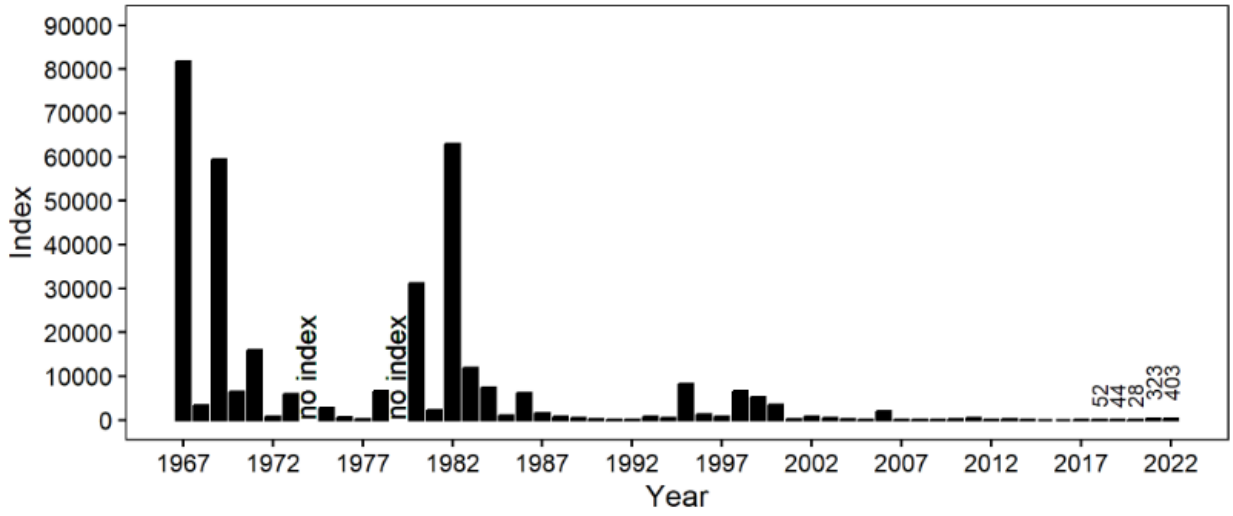
Longfin smelt are anadromous and spawn in fresh or low-salinity water in the Bay-Delta (Grimaldo et al. 2017), generally at 2 years of age (Moyle 2002). They migrate upstream to spawn during late fall through winter, with most spawning from November through April (California Department of Fish and Wildlife 2009a). Previous studies suggested that spawning in the Sacramento River occurs from just downstream of the confluence of the Sacramento and San Joaquin Rivers upstream to about Rio Vista and that spawning on the San Joaquin River extends from the confluence upstream to about Medford Island (Moyle 2002); more recent studies suggest hatching and early rearing occurs in a much broader region and higher salinity (2–12 ppt) than previously recognized (Grimaldo et al. 2017), and includes portions of the south San Francisco Bay (Lewis et al. 2020). Spawning locations have been estimated using field observations of gravid females and yolk-sac larvae (Grimaldo et al. 2017; Lewis et al. 2019) and through particle-tracking modeling (Gross et al. 2022) to suggest spawning extends farther seaward than previously thought (Moyle 2002). Based on these studies, longfin smelt appear to spawn in the low-salinity zone where brackish and freshwaters meet (Grimaldo et al. 2017), and in tidal wetlands of south San Francisco Bay and San Pablo Bay when hydrological conditions favor spawning in more seaward regions (Lewis et al. 2020; Grimaldo et al. 2020).

Longfin smelt larvae are most abundant in the water column usually from January through April (Bureau of Reclamation 2008). As previously noted, larval longfin smelt rear in low salinity to brackish water (2–12 ppt; Grimaldo et al. 2017) and in tidal wetlands of San Pablo Bay (Sonoma Creek, Napa River, and Petaluma River) and south San Francisco Bay (Alviso Marsh and salt pond restoration areas) (Hobbs et al. 2015, Lewis et al. 2020). Larger longfin smelt feed primarily on the calanoid copepod *Eurtyemora affinis* before undergoing an ontogenetic diet shift to mysid shrimp when they are > 25 mm (Feyrer et al. 2003; Barros et al. 2022). Copepods and other crustaceans also can be important food items, especially for smaller fish (Bureau of Reclamation 2008).

Longfin smelt in the San Francisco Estuary are broadly distributed in both time and space, and interannual distribution patterns are relatively consistent (Rosenfield and Baxter 2007). Juveniles gradually move seaward as they grow and as water temperatures increase in the late spring and early summer (Rosenfield and Baxter 2007; Tobias and Baxter 2021). Seasonal patterns in abundance and occurrence in the nearshore ocean suggest that the population is at least partially anadromous (Rosenfield and Baxter 2007; Garwood 2017), and the detection of longfin smelt within the estuary throughout the year suggests that, similar to striped bass, anadromy is one of several life history strategies or contingents in this population. Geochemical analysis of longfin smelt otoliths has provided further evidence of longfin smelt utilizing several life history strategies (Lewis et al. 2019).

The relative population size of longfin smelt in the San Francisco Estuary is measured by indices of abundance generated from different sampling programs. The abundance of age 0 and older fish is indexed by the Fall Midwater Trawl and Bay Study, while the abundance of larvae and young juveniles is indexed by the smelt Larval Survey and 20-mm survey. The relationship between these indices and actual population sizes is unknown. Although the Fall Midwater Trawl data suggest a sharp decline in longfin smelt abundance during the last decade, some of that decline might be attributable to downstream movement in the longfin distribution into regions better sampled by the Bay Study fish survey, which surveys into the San Francisco Bay. The Bay Study uses two types of trawls, an otter trawl and a midwater trawl. The longfin smelt abundance index created from the Fall Midwater Trawl is consistent with the trend in the Bay Study midwater trawl but not with the Bay Study otter trawl. In addition, there has been an increasing proportion of false zeros in the survey data where the Bay Study midwater trawl failed to detect any longfin smelt when they were detected in the otter trawl.

The trend in longfin smelt abundance from the Fall Midwater Trawl, 1967 through 2022, is presented in Figure O-9. The abundance of longfin smelt in the estuary has been very low since 2000, and exhibited statistically significant step-declines around 1989 to 1991 and in 2004 (Thomson et al. 2010).The Fall Midwater Trawl does not cover the entire geographic and seasonal distribution of longfin smelt; the spatial-temporal domain of longfin smelt using multiple survey and monitoring programs is presented in Appendix AB-C, *Species Spatial-Temporal Domains*. Increased Delta outflow in winter and spring is the largest factor possibly affecting longfin smelt abundance (U.S. Fish and Wildlife Service 2012; Nobriga and Rosenfield (2015). Other studies have found a negative relationship between increasing X2 (and therefore freshwater flow) and decreasing longfin smelt abundance (Kimmerer et al. 2009).



Source: California Department of Fish and Wildlife 2022c.

Figure O-9. Fall Midwater Trawl Annual Abundance Indices for Longfin Smelt, 1967–2022

Habitat for longfin smelt is open water, largely away from shorelines and vegetated inshore areas except perhaps during spawning (Grimaldo et al. 2017). This habitat includes all of the large embayments in the estuary and the deeper areas of many of the larger channels in the western Delta; habitat suitability in these areas for longfin smelt can be strongly influenced by variation in freshwater flow (Jassby et al. 1995; Bennett and Moyle 1996; Kimmerer 2004; Kimmerer et al. 2009; Maunder et al. 2015).

Water exports and inadvertent entrainment at the SWP and CVP export facilities are anthropogenic sources of mortality for longfin smelt. The export facilities are known to entrain most species of fish in the Delta (Brown et al. 1996). Longfin smelt entrainment mainly occurs from December to May, with peak adult entrainment from December to February (Grimaldo et al. 2009). In water year 2011, Aasen (2012) reported four adult longfin smelt were salvaged at the project export facilities, compared with much higher numbers in the early 2000s and late 1980s. Increased freshwater flows create more ideal spawning habitat areas further seaward away from the Delta (Grimaldo et al. 2020). The entrainment of longfin smelt in recent years has been reduced, likely because of changes in export operations and a decline in abundance. Kimmerer and Gross (2022) found that modeled proportional loss of larvae from exports averaged 1.5% of the population, while results from Gross et al. (2022) found proportional entrainment varied from nearly 0% during a wet year to 2% during a dry year.

Pacific Lamprey

The Pacific lamprey is a widely distributed species that uses the Delta for upstream migration as adults, for downstream migration as juveniles, and for rearing as ammocoetes (Hanni et al. 2006; Moyle et al. 2009). Pacific lampreys are present in the north, central, and south Delta, and ammocoetes are present year-round in all of the regions (California Department of Water Resources et al. 2013). Limited information on status of Pacific lamprey in the Delta exists, but the number of lampreys inhabiting the Delta is likely greatly suppressed compared with historical levels, as suggested by the loss of access to historical habitat and apparent population declines throughout California and the Sacramento–San Joaquin River basin (Moyle et al. 2009).

Limited data indicate most adult Pacific lamprey migrate though the Delta enroute to upstream holding and spawning grounds in the early spring through early summer (Hanni et al. 2006). As documented in other large river systems, it is likely that some adult migration through the Delta occurs from late fall and winter through summer and possibly over an even broader period (Robinson and Bayer 2005; Hanni et al. 2006; Moyle et al. 2009; Clemens et al. 2012; Lampman 2011). Data from the Fall Midwater Trawl Survey in the lower Sacramento and San Joaquin Rivers and Suisun Bay suggest that peak out-migration of Pacific lamprey through the Delta coincides with high-flow events from fall through spring (Hanni et al. 2006). Some out-migration likely occurs year-round, as observed at sites farther upstream (Hanni et al. 2006) and in other river systems (Moyle 2002). Some Pacific lamprey ammocoetes likely spend part of their extended (3 to 7 years) freshwater residence rearing in the Delta, particularly in the upstream, freshwater portions (California Department of Water Resources et al. 2013).

Western River Lamprey

The Sacramento and San Joaquin River basins are at the southern edge of the range for Western river lamprey (Moyle et al. 2009). While their population abundance is poorly understood, they are frequently caught in the Delta Juvenile Fish Monitoring Program in the winter months through trawls at Sherwood Harbor, Mossdale, and Chipps Island (Interagency Ecological Program et al. 2022). It is hypothesized that their presence in the Bay-Delta is part of their migration to tributaries in the San Francisco Estuary (Napa River, Sonoma Creek, Alameda Creek), and tributaries to the Sacramento and San Joaquin rivers (e.g., Tuolumne River, Stanislaus River, Cache Creek) (Moyle et al. 2015). Ammocoetes spend an unknown amount of time as ammocoetes (likely 3-5 years) in silt-sand backwater eddies and have been documented during dredging studies in the Delta (Lamprey Technical Workgroup 2021; Moyle et al. 2015). Adults typically start their migration back into their natal habitats in the fall.

Sacramento Splittail

Sacramento splittail are found primarily in marshes, turbid sloughs, and slow-moving river reaches throughout the Delta subregion (Sommer et al. 1997, 2008). Sacramento splittail are most abundant in moderately shallow, brackish tidal sloughs and adjacent open-water areas, but they also can be found in freshwater areas with tidal or riverine flow (Moyle et al. 2004).

Adult Sacramento splittail typically migrate upstream from brackish areas in January and February and spawn in freshwater, particularly on inundated floodplains when they are available, in March and April (Sommer et al. 1997; Moyle et al. 2004; Sommer et al. 2008). A substantial amount of splittail spawning occurs in the Yolo and Sutter Bypasses and the Cosumnes River area of the Delta (Moyle et al. 2004). Spawning also can occur in the San Joaquin River during high-flow events (Sommer et al. 1997, 2008). However, not all adults migrate significant distances to spawn, as evidenced by the genetically distinct population spawning in the Napa and Petaluma Rivers (Feyrer et al. 2005; Baerwald et al. 2007).

Although juvenile Sacramento splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks or months of rearing in floodplain habitats along the rivers (Feyrer et al. 2006). Juveniles move downstream into the Delta from April to August (Meng and Moyle 1995; Feyrer et al. 2005). Sacramento splittail recruitment is largely limited by extent and period of inundation of floodplain spawning habitats, with abundance observed to spike following wet years and dip after dry years (Moyle et al. 2004). However, the 5- to 7-year life span buffers the adult population abundance (Sommer et al. 1997; Moyle et al. 2004). Other factors that may adversely affect the Sacramento splittail population in the Delta include entrainment, predation, changed estuarine hydraulics, nonnative species (Moyle et al. 2004), pollutants (Greenfield et al. 2008), and limited food.

Hardhead

The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are present in low abundance in the San Francisco Estuary and Delta. Brown and Michniuk (2007) electrofished parts of the Bay-Delta in the 1980's and 2000's and captured small numbers of hardhead. Retrieval of hardhead at the SWP/CVP south Delta fish salvage facilities remain relatively low (California Department of Water Resources 2020). The three trawl surveys (Sherwood Harbor, Chipps Island, and Mossdale) caught 32 hardhead in 2012 but typically

capture rates are relatively low throughout the upper San Franciso Estuary, with less than 10 individuals were captured annually between 2013 and 2022 (Interagency Ecological Program et al. 2022). In other parts of their range, populations have declined or have become increasingly isolated (Moyle 2002). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Hardhead*.

Sacramento Hitch

Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin valleys and in the Delta. Within the San Francisco Estuary and Delta vicinity, there are historical records (from before the water development of the 1950s) for Sacramento hitch in Coyote Creek and Alameda Creek. However, the species may have been introduced to Arroyo Valle through water transfers from the Central Valley. Furthermore, it is unknown if populations in these streams are reproducing or are sustained from reservoir or historical stream populations (Leidy 2007). The species is distributed in the Sacramento River Basin, in low numbers in the San Joaquin River Basin, and occasionally captured during monitoring programs in the Delta (Moyle et al. 2015; Interagency Ecological Program et al. 2022). In the three trawl surveys (Sherwood Harbor, Chipps Island, and Mossdale), less than 10 individuals were captured annually throughout the upper San Francisco Estuary between 2002 and 2022 (Interagency Ecological Program et al. 2022). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Sacramento Hitch*.

American Shad

American shad is an important anadromous species introduced into the Sacramento–San Joaquin River basin in the 1870s (Moyle 2002). American shad spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento, Feather, American, and Yuba Rivers. Some spawning also takes place in the lower San Joaquin, Mokelumne, and Stanislaus Rivers (U.S. Fish and Wildlife Service 1995). The spawning migration may begin as early as February, but most adults migrate into the Delta in March and early April (Skinner 1962). Migrating adults generally take 2 to 3 months to pass through the Sacramento–San Joaquin estuary (Painter et al. 1979).

Fertilized eggs are slightly negatively buoyant, are not adhesive, and drift in the current. Newly hatched larvae are found downstream of spawning areas and can be rapidly transported downstream by river currents because of their small size. Juvenile American shad rear in the Sacramento River below Knights Landing, the Feather River below Yuba City, and the Delta; rearing also takes place in the Mokelumne River near the DCC to the San Joaquin River. Some juvenile American shad may rear in the Delta for up to a year before out-migrating to the ocean (U.S. Fish and Wildlife Service 1995). Out-migration from the Delta begins in late June and continues through November (Painter et al. 1979).

Juvenile American shad are frequently encountered in the Delta during the Fall Midwater Trawl Survey and in fish salvage monitoring at the south Delta SWP and CVP fish facilities (California Department of Water Resources et al. 2013). American shad use of the Delta has been observed to vary with salinity (e.g., X2 position) and outflows (Kimmerer 2002a).

American shad are entrained at the TFCF (Bowen et al. 1998) and in the Clifton Court Forebay, mostly during May through December when young American shad migrate downstream. The American shad population in the Sacramento–San Joaquin River basin has declined since the late 1970s, most likely because of increased diversion of water from rivers and the Delta, combined with changing ocean conditions, and possibly pesticides (Moyle 2002). Historic salvage information on American shad is available publicly online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Threadfin Shad

Threadfin shad were introduced in reservoirs throughout California to provide forage for game fish, with the Sacramento and San Joaquin River basins introductions starting as early as 1959. From these transplants, they have become established in the Sacramento–San Joaquin River system and the Delta. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most commonly encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. They are fished commercially in the San Francisco Estuary and Delta and sold as bait to sport anglers (Feyrer et al. 2009). For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Threadfin Shad*.

Striped Bass

Striped bass is a recreationally important anadromous species introduced into the Sacramento–San Joaquin River basin between 1879 and 1882 (Moyle 2002). Despite their nonnative status and piscivorous feeding habits, striped bass are considered important because they are a major game fish in the Delta. Striped bass use the Delta as a migratory route and for rearing and seasonal foraging. Striped bass spend the majority of their lives in salt water, returning to freshwater to spawn. When not migrating for spawning, adult striped bass in the Bay-Delta are found in San Pablo Bay, San Francisco Bay, and the Pacific Ocean (Moyle 2002). Adult striped bass spend about 6 to 9 months of the year in San Francisco and San Pablo Bays (Hassler 1988). Striped bass also use deeper areas of many of the larger channels in the Delta, in addition to large embayments such as Suisun Bay.

Spawning occurs in spring, primarily in the Sacramento River between Sacramento and Colusa and in the San Joaquin River between Antioch and Venice Island (Farley 1966). Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all striped bass eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

YOY striped bass distribute themselves in accordance with the estuarine salinity gradient (Kimmerer 2002a; Feyrer et al. 2007), indicating that salinity is a major factor affecting their habitat use and geographic distributions. Kimmerer (2002a) found that distributions of fish species, including striped bass, substantially overlapped with the low salinity zone. Older striped bass are increasingly flexible about their distribution relative to salinity (Moyle 2002).

The entrainment of striped bass has been observed at the project export facilities, including Clifton Court Forebay (Stevens et al. 1985; Bowen et al. 1998; Aasen 2012). Salvage of striped bass at export facilities historically has been variable but there has generally been a trend of low observations since the mid-1990s. Prior to 1995, annual striped bass salvage was generally above 1 million fish (Aasen 2012). DWR et al. (2013) reported that striped bass longer than 24 mm were effectively screened at TFCF and bypassed the pumps. However, planktonic eggs, larvae, and juveniles smaller than 24 mm in length received no protection from entrainment. Historic salvage information on striped bass is available publicly online at https://apps.wildlife.ca.gov/Salvage/ and https://filelib.wildlife.ca.gov/Public/Salvage/.

Striped bass, primarily YOY, are one of the pelagic fish of the upper estuary that have shown substantial variability in their populations, with evidence of long-term declines (Kimmerer et al. 2000; Sommer et al. 2007a). As discussed earlier for Delta smelt, a substantial portion of the abundance patterns has been associated with variation of outflow in the estuary (Jassby et al. 1995; Kimmerer et al. 2001; Loboschefsky et al. 2012), although this is disputed by some stakeholders (Bourez 2011). However, surveys showed that population levels for YOY striped bass began to decline sharply around 1987 and 2002 (Thomson et al. 2010), despite relatively moderate hydrology, which typically supports at least modest fish production (Sommer et al. 2007a). Moyle (2002) cites causes of decline in striped bass to include climatic factors, entrainment at project export facilities in the south Delta, other diversions, pollutants, reduced estuarine productivity, invasions by alien species, and human exploitation. Kimmerer et al. (2000, 2001) attribute the decline in juvenile YOY striped bass to declining carrying capacity, likely related to food limitation. Loboschefsky et al. (2012) showed that there had been no long-term decline for age one and older striped bass as of 2004.

Black Basses

Three *Micropterus* spp. constitute the group of black basses in California, and include largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species). All three species are found within the Bay-Delta. For general life history information applicable to all Central Valley rivers and tributaries, see Section O.1.3.3, *Black Basses*.

Starry Flounder

Starry flounder have a wide range along the Pacific coast, from north of the Bering Strait to Los Angeles Harbor in the south. Most juveniles are found in shallow, fresh to brackish water, and shift to salinities of 10–15 ppt as they mature, but appear to remain within estuaries through at least their second year (Baxter et al. 1999; Moyle 2002). During the late fall and winter, mature starry flounder probably migrate to shallow coastal waters to spawn (Orcutt 1950). Adults primarily inhabit coastal marine waters (Orcutt 1950; Haertel and Osterberg 1967; Bottom et al. 1984; Hieb and Baxter 1993). Distribution of age-0 juveniles within the San Francisco Estuary and Delta is primarily in Suisun Bay and San Pablo Bay, with lower abundance in the west Delta (Baxter et al. 1999). Starry flounder older than age 1 (age-1+ fish) occur principally in San Pablo Bay, Suisun Bay, and Central Bay (Baxter et al. 1999).

Abundance indices from the past decade suggest a general decline relative to several decades ago, consistent with declines in commercial and recreational catch (ICF International 2016). Starry flounder are found on different substrates including: gravel, clean shifting sand, hard stable sand, and mud substrata, but fishermen report the largest catches over soft sand. Starry

flounder can tolerate a wide range of salinities. In the Sacramento and San Joaquin Rivers, starry flounder have been observed in salinities of 0.02–0.06 ppt (i.e., essentially fresh water) (Orcutt 1950). Age-0 and age-1+ starry flounder are a common species in estuarine habitats along the West Coast (see Orcutt 1950; Pearson 1989; Emmett et al. 1991; Baxter et al. 1999; Kimmerer 2002b).

Spawning occurs primarily during the winter months of December and January (Orcutt 1950). Starry flounder reach approximately 110 mm (4.34 inches) in length by the end of their first year. By the time they reach age 2 many fish have migrated to ocean habitats adjacent to their natal estuaries. Starry flounder become reproductively mature at age-2 for males and age-3 for females, which equates to approximately 28 cm (11.02 inches) in males and approximately 35 cm (13.78 inches) in females. Adults may move seasonally into shallow coastal waters to spawn, perhaps in proximity to estuaries to take advantage of estuarine circulation which would advect fertilized eggs near the bottom into nursery areas.

Hieb and Baxter (1993) established specific habitat criteria for starry flounder YOY (<70 mm) in the San Francisco Estuary: 90% were collected from intertidal and subtidal habitats <7 m in depth, and with accompanying salinities of <22%. The exclusivity of fresh and brackish water rearing habitat in age-0 and age-1 starry flounder coupled with the relationship between freshwater outflow and abundance makes a strong case for estuarine dependence (Emmett et al. 1991:267; Hieb and Baxter 1993). However, spawning in coastal areas and variation in abundance during high outflow years suggest that coastal ocean conditions as well as high outflow work in conjunction to determine year class abundance (Hieb and Baxter 1993). There is a significant correlation between Delta outflow (X2) and indices of starry flounder abundance in the San Francisco Estuary and Delta, although the mechanism underlying the correlation does not appear to be related to extent of habitat and may be related to enhanced transport to estuarine rearing grounds by increased residual circulation with increased outflow (Kimmerer et al. 2009). It is unknown the extent to which this potential enhanced transport and apparent greater abundance in the San Francisco Estuary and Delta with greater outflow may contribute to overall coastwide starry flounder abundance (Grimaldo 2018).

Coastal Pelagic Species

Northern anchovy (*Engraulis mordax*) is a species for which EFH exists in the San Francisco Estuary and Delta and is one of the species managed under the Coastal Pelagic Species Fishery Management Plan (FMP). The overall extent of Coastal Pelagic EFH is based on a thermal range bordered by the geographic area where the managed coastal pelagic species in the FMP occur at any life stage, where these species have occurred historically during periods of similar environmental conditions, or where environmental conditions do not preclude colonization by these species. Species diversity and abundance declines on an upstream gradient as determined by the tolerance of individual species for low and variable salinity conditions.

Northern anchovy is distributed along the West Coast from British Columbia to Baja, California (Miller and Lea 1972). The central subpopulation, which is present in the project area, ranges from approximately San Francisco, California, to Punta Baja, Baja California. Members of the central population move north during the summer and south during the winter (Haugen et al. 1969). Northern anchovy is an important forage fish for other resident and migratory species in the San Francisco Estuary and Delta, including salmon, jacksmelt (*Atherinopsis califoniensis*),

and striped bass (Baxter et al. 1999:167). It supports a moderate commercial fishery for live bait (Smith and Kato 1979). The annual abundance of northern anchovy is highly variable between years. Surveys have shown that the greatest densities occur in Central, San Pablo, and South Bays, and only in late summer were they collected in appreciable numbers in Suisun Bay (Baxter et al. 1999).

Northern anchovy is a small fish typically found in schools near the surface of the water. They are short-lived, rarely living past 4 years of age. A portion of the population reaches maturity at the end of their first year, about 50% by the end of their second year, and all are mature by their third or fourth year (Clark and Phillips 1952). Female anchovy are batch spawners, spawning 20,000 to 30,000 eggs a year in two or three events (Baxter 1967). Spawning can occur during every month of the year and is temperature dependent, increasing in late winter and early spring and peaking from February to April. They spawn in nearshore areas across their entire range, in the upper 50 meters of the water column. Spawning in the bay occurs at higher temperatures and lower salinities than spawning in coastal areas (Emmett et al. 2005; Bergen and Jacobson 2001). Both northern anchovy eggs and larvae are found near the surface, and eggs need 2 to 4 days to hatch, depending on water temperatures. The San Francisco Bay is a very productive nursery area because of high abundance of food for both larvae and adults, advective losses are lower than in adjacent coastal waters, and the bay is warmer, with varying salinity allowing for eggs and larvae throughout the year (Bureau of Reclamation 2008). Anchovies feed diurnally either by filter feeding or biting, depending on the size of the food. Juvenile and adult anchovy feed at a higher trophic level than larvae, selectively feeding on larger zooplankton (mysids), fish eggs, and fish larvae and have been observed to eat small fish at times, even their own species (Baxter 1967).

Larvae eat phytoplankton and dinoflagellates, while larger larvae pick up copepods and other zooplankton. Larger female anchovies can consume up to 4%–5% of their total body weight per day. Competitors with the anchovy for food include sardines and other schooling planktivores, such as jacksmelt and topsmelt (Atherinops affinis). These species are also potential predators of young anchovy life stages (Goals Project 2000).

Factors affecting anchovy production are mostly natural influences, such as ocean temperature (California Department of Fish and Game 2001b). Offshore within the California Current, temperature, upwelling, and stable stratification of the water column are believed to work together to produce conditions that are favorable to anchovy larvae (Lasker 1975). Investigation of the correlations between Delta outflow (X2) and indices of abundance and habitat did not find statistically significant relationships (Kimmerer et al. 2009). The distribution of northern anchovy shifted toward higher salinity when Potamocorbula invaded in the mid- to late 1980s, reducing summer abundance by >90% in the low-salinity region of the San Francisco Estuary and Delta (Kimmerer 2006).

In the San Francisco Bay Estuary, the Pacific herring (*Clupea pallasii*) support a historical and culturally important fishery. Four areas within the state of California support spawning stocks large enough to support a fishery, with San Franscisco Bay accounting for over 90% of the landings (California Department of Fish and Wildlife 2019). In California, Pacific herring are also found in Humboldt Bay and Tomales Bay. Pacific herring also support a commercial fishing industry for the roe, and the species is commonly used as bait for recreational fishing. Pacific

herring also supports a year-round recreational fishery, where up to ten gallons of Pacific herring may be taken per day.

Pacific herring are a pelagic fish species found throughout the coastal zone from Baja California to Alaksa and across the north Pacific to Japan (Spratt 1981). Pacific herring spawning season occurs between November and March, where herring will form schools and move into intertidal and shallow subtidal bays and estuaries (California Department of Fish and Wildlife 2015, Spratt 1981). Herring in San Francisco Bay will utilize eelgrass, riprap, pilings, and other natural and manmade structures to adhere their eggs during spawning. Embryos hatch in 8-14 days, determined mainly by water temperature (California Department of Fish and Wildlife 2015, Vines et al. 2000). After spawning, Pacific herring will move out of the bay and may travel over 150 kilometers per week (Carls et al. 2008, Watters et al. 2004), while young of the year individuals may remain in the bay until summer before emigrating offshore (Fleming 1999, Watters et al. 2004). In San Francisco Bay, larval herring feed on tintinnids, a single-celled microzooplankton (Bollens and Sanders 2004), while juveniles feed on micro-plankton (Purcell and Grover, 1990) and adults will feed on plankton throughout their lifecycle, relying heavily on visual cues in feeding (Blaxter and Holiday 1963). Threats to Pacific herring in San Francisco Bay include damage to spawning habitat from activities like construction, shoreline development, pile driving, dredging, urban run-off, invasive species, freshwater diversion, vessel traffic, and pollutants (California Department of Fish and Wildlife 2019), as well as overfishing.

O.1.9.2 Aquatic Habitat

Delta

Flow management in the Delta has created stress on aquatic resources by (1) changing aspects of the historical flow regime (timing, magnitude, duration) that supported life history traits of native species; (2) limiting access to or quality of habitat; (3) contributing to conditions better suited to invasive, nonnative species (reduced spring flows, increased summer inflows and exports, and low and less-variable interior Delta salinity (Moyle and Bennett 2008); and (4) causing reverse flows in channels leading to project export facilities that can entrain fish (Mount et al. 2012). Native species of the Delta are adapted to and depend on variable flow conditions at multiple scales as influenced by the region's dramatic seasonal and interannual climatic variation. In particular, most native fish evolved reproductive or out-migration timing associated with historical peak flows during spring (Moyle 2002).

Water temperatures in the Delta follow a seasonal pattern of winter cold water conditions and summer warm water conditions, largely because of the region's Mediterranean climate, with alternating cool-wet and hot-dry seasons. Currently in the Delta, the most significant changes in water temperatures have been in the form of increased summer water temperatures over large areas of the Delta because of high summer ambient air temperatures, the increased temperature of river inflows, and to a lesser extent, reduced quantities of freshwater inflow and modified tidal and groundwater hydraulics (Kimmerer 2004; Mount et al. 2012; National Research Council 2012; Wagner et al. 2011). Water temperatures in summer now approach or exceed the upper thermal tolerances (e.g., 20ºC to 25°C) for cold water fish species such as salmonids and Delta-dependent species such as Delta smelt. This is especially true in parts of the south Delta and San Joaquin River, potentially restricting the distribution of these species and precluding previously important rearing areas (National Research Council 2012).

Landscape-scale changes resulting from flood management infrastructure, along with flow modification, have eliminated most of the historical hydrologic connectivity of floodplains and aquatic ecosystems in the Delta and its tributaries, thereby degrading and diminishing Delta habitat for native plant and animal communities (Mount et al. 2012). The large reduction of hydrologic variability and landscape complexity, coupled with degradation of water quality, has supported invasive aquatic species that have further degraded conditions for native species. Due to the combination of these factors, the Delta appears to have undergone an ecological regime shift unfavorable to many native species (Moyle and Bennett 2008; Baxter et al. 2010). Historically, several major species abundances have correlated with Delta hydrology including Delta smelt, longfin smelt, Sacramento splittail, white sturgeon, juvenile Chinook salmon, and striped bass (Jassby et al. 1995; Kimmerer 2002a; Rosenfield and Baxter 2007; Kimmerer et al. 2009; Fish 2010; Perry et al. 2012; Thomson et al. 2010; Loboschefsky et al. 2012; Mount et al. 2012). Over time, some of these correlations have changed and/or their predictive power has declined (Tamburello et al 2018), likely due to environmental perturbations and can only be partially explained by changes in water operations (Kimmerer 2002a; Thomson et al. 2010). Changes in hydrology may act synergistically with other environmental factors (e.g. low turbidity, high temperatures) to reduce quality and quantity of habitat available to fish species (Castillo et al. 2018).

Salinity is a critical factor influencing plant and animal communities in the Delta. Although estuarine fish species are generally tolerant of a range of salinity, this varies by species and life stage. Some species can be highly sensitive to excessively low or high salinity during physiologically vulnerable periods, such as reproductive and early life history stages. Although the Delta is tidally influenced, most of the Delta is freshwater year-round, due to inflows from rivers. The south Delta can have low salinity because of agricultural return water. The tidally influenced low salinity zone can move upstream into the central Delta.

An important measure of the spatial geography of salinity in the western Delta is X2. The X2 has also been correlated with the amount of suitable habitat for Delta smelt in fall (Feyrer et al. 2007; 2010; U.S. Fish and Wildlife Service 2008). It also helps define the extent of habitat available for oligohaline pelagic organisms and their prey. An analysis of historical monitoring data by Feyrer et al. (2007) revealed that the abiotic habitat of Delta smelt can be defined as a specific envelope of salinity and turbidity that changes over the course of the species' life cycle. Project operations and other potential factors (e.g., lower outflows) have tended to shift the X2 position in fall farther upstream out of the wide expanse of Suisun Bay into the much narrower channels near the confluence of the Sacramento and San Joaquin Rivers (near Collinsville), reducing the spatial extent of low salinity habitat important for relevant species such as Delta smelt (U.S. Fish and Wildlife Service 2008, 2011a; Kimmerer et al. 2009; Baxter et al. 2010). However, there is emerging information suggesting that a comparison of the Delta outflow during pre-project and post-project time periods do not support the conclusion that project operations have significantly moved X2 more easterly in September and October compared to pre-project conditions and project operations have only potentially affected X2 location in November (Hutton et al. 2015).

Turbidity is another important factor that influences the aquatic community and fish behaviors in the Delta. Fish in more turbid conditions are less likely to be consumed by predators, experience lower stress, and experience altered feeding success (Ferrari et al. 2013, Hasenbein et al. 2013, Hassenbein et al. 2016; Schreier et al. 2016; Pasparakis et al. 2023). Loss of important fish

habitat may be exacerbated by invasive submerged aquatic vegetation (SAV) which can lower sedimentation rate, creating clearer conditions which then leads to increase coverage by SAV, creating a feedback loop by allowing the SAV to further proliferate (Hestir et al. 2015, Christman et al. 2023). This may also benefit non-native predators that utilize SAV as habitat, which is why entrainment of fish into the South Delta is associated with higher risk of predation (Brown and Michniuk 2007; Castillo et al. 2012; Durand et al. 2016). Turbidity is also an indication of first flush conditions, which is caused by increased water flow from the first major storms of the season and serves as a cue for the spawning migration of Delta smelt (Sommer et al. 2011). CVP and SWP operations export operations are now managed using turbidity as a metric to trigger turbidity bridge actions meant to reduce the risk of forming a turbidity bridge and reduce the risk of entrainment of adult Delta smelt at export facilities.

Yolo Bypass

Aquatic habitats in the Yolo Basin include stream and slough channels for fish migration, and when flooded, seasonal spawning habitat and productive rearing habitat (Sommer et al. 2001a; CALFED Bay-Delta Program 2000a, 2000b). During years when the Yolo Bypass is flooded, it serves as an important migratory route for juvenile Chinook salmon and other native migratory and anadromous fishes moving downstream. During these times, it provides juvenile anadromous salmonids an alternative migration corridor to the lower Sacramento River (Sommer et al. 2003) and, sometimes, better rearing conditions than the adjacent Sacramento River channel (Sommer et al. 2001a, 2005). When the floodplain is activated, juvenile salmon can rear for weeks to months in the Yolo Bypass floodplain before migrating to the estuary (Sommer et al. 2001a). Research on the Yolo Bypass has found that juvenile salmon grow substantially faster in the Yolo Bypass floodplain than in the adjacent Sacramento River, primarily because of greater availability of invertebrate prey in the floodplain (Sommer et al. 2001a, 2005). When not flooded, the lower Yolo Bypass provides tidal habitat for young fish that enter from the lower Sacramento River via Cache Slough Complex (McLain and Castillo 2009; California Department of Water Resources unpublished data).

Sommer et al. (1997) demonstrated that the Yolo Bypass is one of the single most important habitats for Sacramento splittail. Because the Yolo Bypass is dry during summer and fall, nonnative species (e.g., predatory fish) generally are not present year-round except in perennial water sources (Sommer et al. 2003). In addition to providing important fish habitat, seasonal inundation of the Yolo Bypass supplies phytoplankton and detritus that may benefit aquatic organisms downstream in the brackish portion of the San Francisco Estuary (Sommer et al. 2004; Lehman et al. 2008). Floodplains can be important and highly productive seasonal rearing habitat for native fish species (Sommer et al. 2020). The benefits can extend beyond floodplains as inundation of flood bypasses can provide prey subsidies to fish further downstream (Frantzich et al. 2021; Sturrock et al. 2022). Off-channel floodplain habitat is critical for Central Valley Chinook salmon because it provides food resources (Sommer et al. 2001a), increased rearing habitat (Cordell et al. 2011), and the duration of flooding positively affects fish body condition (Takata et al. 2017). Loss of this habitat leaves juvenile salmonids without access to these beneficial resources. The Big Notch Project is anticipated to divert both water and fish from the mainstem Sacramento River onto the Bypass after a threshold river stage is met, connecting the Bypass and the Sacramento. This is anticipated to provide seasonal inundation that mimics the natural process of the Yolo Bypass floodplain, which may benefit a number of native fish

including spawning habitat for Sacramento splittail. Additionally, a fish passage structure at Freemont Weir may provide an exit for otherwise possibly stranded fish when river stage drops.

Suisun Bay and Marsh

Suisun Marsh is a brackish-water marsh bordering the northern edge of Suisun Bay. Most of its marsh area consists of diked wetlands managed for waterfowl, with the rest of the acreage consisting of tidally influenced sloughs (Suisun Ecological Workgroup 2001). The central latitudinal location of Suisun Marsh within the San Francisco Estuary makes it an important rearing area for euryhaline freshwater, estuarine, and marine fish. Many fish species that migrate or use Delta habitats are also found in the waters of Suisun Bay. Tides reach Suisun Bay and Marsh through the Carquinez Strait, and most freshwater flows enter at the southeast border of Suisun Marsh at the confluence of the Sacramento and San Joaquin Rivers. The mixing of freshwater outflows from the Central Valley with saline tidal water in Suisun Bay and Suisun Marsh results in brackish water with strong salinity gradients, complex patterns of flow interactions, and generally the highest biomass productivity in the entire estuary (Siegel et al. 2010).

Although the fish assemblages in Suisun Bay and Marsh can differ substantially from the fish assemblages in the Delta, all the species that use the Delta also use Suisun Bay and Marsh. In years of drought, warmer climate and warmer saltier water, fish assemblages in Suisun Marsh have higher proportions of marine born species than those which normally spawn in freshwater (O'Rear et al. 2022).

Flow, turbidity, and salinity are important factors influencing the location and abundance of zooplankton and small prey organisms used by Delta species (Kimmerer et al. 1998). The location where net current flowing inland along the bottom reverses direction and sinking particles are trapped in suspension is associated with higher turbidity known as the estuarine turbidity maximum. Burau et al. (2000) reports that the estuarine turbidity maximum occurs near the Benicia Bridge and in Suisun Bay near Garnet Point on Ryer Island. Zooplanktonic organisms maintain position in this region of historically high productivity in the estuary through vertical movements (Kimmerer et al. 1998).

Salinity in the Suisun Bay and Marsh system is a major water quality characteristic that strongly influences physical and ecological processes. Fish species native to Suisun Marsh require low salinities during the spawning and rearing periods (Suisun Ecological Workgroup 2001; Kimmerer 2004; Feyrer et al. 2007, 2010; Nobriga et al. 2008). Suisun Bay and Marsh usually contain both the maximum estuarine salinity gradient and the low salinity zone. The overall estuarine salinity gradient trends from west (higher) to east (lower) in Suisun Bay and Marsh. The location of the low salinity zone gradient and X2 can be influenced by outflow. Suisun Marsh also exhibits a persistent north-south salinity gradient.

The Suisun Bay and Marsh system contains a wide variety of habitats such as marsh plains, tidal creeks, sloughs, channels, cuts, mudflats, and bays. These features and the complex hydrodynamics and water quality of the system have historically fostered significant biodiversity within Suisun tidal aquatic habitats, but, like the Delta, these habitats also have been significantly altered and degraded by human activities over the decades.

Categories of tidal aquatic habitat were identified as part of the Suisun Marsh Plan development process and were defined using physical boundaries; habitats include bays, major sloughs, minor sloughs, and the intertidal mudflats in those areas (Engle et al. 2010). These tidal habitats total approximately 26,000 acres, with the various embayment's totaling about 22,350 acres. Tidal slough habitat is composed of major and minor sloughs, with major sloughs of Suisun Marsh having a combined acreage of about 2,200 acres consisting of both shallow and deep channels. Minor sloughs are made up of shallow channel habitat and have a combined acreage of about 1,100 acres. Habitats in Suisun Marsh bays and sloughs support a diverse assemblage of aquatic species that typically use open water tidal areas for breeding, foraging, rearing, or migrating.

Ongoing management of Suisun Marsh includes multiple actions that may affect fish species. For example, operations of the Suisun Marsh Salinity Control Gates (SMSCG) were modified in the summer of 2018 to allow for a flow pulse meant to increase habitat suitability for Delta smelt. The flow pulse did improve some habitat conditions (turbidity and chlorophyll) but did not have an effect on others (prey availability) (Sommer et al. 2020). Ongoing restoration efforts in Suisun Marsh are aimed at restoring tidal and sub-tidal wetland habitat for multi-species benefits to mitigate effects from water export operations (Moyle et al. 2013; California Department of Water Resources 2024). Changes to the fish and invertebrate community in Suisun Marsh have been documented by a decades long monitoring project using otter trawls and beach seines run by UC Davis (O'Rear et al. 2021). The data from the project has been used to document long term declines in native fish abundances in Suisun Marsh (Matern et al. 2002).

O.1.9.3 Nutrients and Food Web Support

Nutrients are essential components of terrestrial and aquatic environments because they provide a resource base for primary producers. Typically, in freshwater aquatic environments, phosphorous is the primary limiting macronutrient, whereas in marine aquatic environments, nitrogen tends to be limiting. A balanced range of abundant nutrients provides optimal conditions for maximum primary production, a robust food web, and productive fish populations. However, changes in nutrient loadings and forms, excessive amounts of nutrients, and altered nutrient ratios can lead to eutrophication and a suite of problems in aquatic ecosystems, such as low DO concentrations, un-ionized ammonia, excessive growth of toxic forms of cyanobacteria, and changes in components of the food web. Nutrient concentrations in the Delta have been well studied (Jassby et al. 2002; Kimmerer 2004; Van Nieuwenhuyse 2007; Glibert 2010; Glibert et al. 2011, 2014).

Estuaries are commonly characterized as highly productive nursery areas for numerous aquatic organisms. Nixon (1988) noted that there is a broad continuum of primary productivity levels in different estuaries, which in turn affects fish production and abundance. Compared to other estuaries, pelagic primary productivity in the upper San Francisco Estuary is relatively poor, and a relatively low fish yield is expected (Wilkerson et al. 2006). In the Delta and Suisun Marsh, this appears to result from turbidity, clam grazing (Jassby et al. 2002), and nitrogen and phosphorus dynamics (Wilkerson et al. 2006; Van Nieuwenhuyse 2007; Glibert 2010; Glibert et al. 2014).

There has been a significant long-term decline in phytoplankton biomass (chlorophyll a) and primary productivity to low levels in the Suisun Bay region and the Delta (Jassby et al. 2002). Shifts in nutrient concentrations such as high levels of ammonium and nitrogen to phosphorus ratio may contribute to the phytoplankton reduction and to changes in algal species composition in the San Francisco Estuary (Wilkerson et al. 2006; Dugdale et al. 2007; Lehman et al. 2005, 2008, 2010; Glibert 2010; Glibert et al. 2014). Low and declining primary productivity in the estuary may be contributing to the long-term pattern of relatively low and declining biomass of pelagic fish (Jassby et al. 2002). Introduction of two clams from Asia have led to major alterations in the food web in the Delta. *Potamocorbula amurensis* is most abundant in the brackish and saline water of Suisun Bay and the western Delta, and *Corbicula fluminea* is most abundant in the freshwater of the central Delta. These filter feeders significantly reduce the phytoplankton and zooplankton concentrations in the water column, reducing food availability for native fish, such as Delta smelt and young Chinook salmon (Feyrer et al. 2007; Kimmerer 2002b; Kayfetz and Kimmerer 2017; Hammock et al. 2019).

Additionally, introduction of the clams led to the decline of native copepods of higher food quality and the establishment of poorer quality nonnative copepods. More recently, the cyclopoid copepod, *Limnoithona*, has rapidly become the most abundant copepod in the Bay-Delta since its introduction in 1993 (Hennessy and Enderlein 2013). This species is may be a poorer quality food item for Delta smelt (Slater and Baxter 2014) and a competitor of native and nonnative calanoid copepods (Gould and Kimmerer 2010). Other non-native predatory copepods such as *Acartiella sinensis* have shifted the range of *Pseudodiaptomus forbesi* further landward away from the low salinity zone (Slaughter et al. 2016). *P. amurensis* has also been implicated in the dramatic reduction of the native mysid shrimp, a preferred food of Delta native fish such as Sacramento splittail and longfin smelt (Feyrer et al. 2003; Winder and Jassby 2011). The native mysid shrimp *Neomysis mercedis* has been replaced by the smaller non-native *Hyperacnthomysis longirostris* (Avila and Hartman 2020). Reductions in food availability and food quality have led to lower fish foraging efficiency and reduced growth rates (Moyle 2002).

Studies on food quality have been relatively limited in the San Francisco Estuary, with even less information on long-term trends. Kratina and Winder (2015) suggest that the nutritional quality of the non-native zooplankton community is not much different from the preceding native community. Nonetheless, several studies have documented or suggested the food limitations for aquatic species in the estuary, including zooplankton (Mueller-Solger et al. 2002; Kimmerer et al. 2005; Winder and Jassby 2011), Delta smelt (Bennett 2005; Bennett et al. 2008), longfin smelt (Barros et al. 2022), Chinook salmon (Sommer et al. 2001b), Sacramento splittail (Greenfield et al. 2008), striped bass (Loboschefsky et al. 2012), and largemouth bass (Nobriga 2009).

O.1.9.4 Turbidity

Turbidity is an important water quality component in the Delta that affects physical habitat through sedimentation and food web dynamics by means of attenuation of light in the water column. Light attenuation, in turn, affects the extent of the photic zone where primary production can occur and the ability of predators to locate prey and for prey to escape predation.

Turbidity has been declining in the Delta, as indicated by sediment data collected by the U.S. Geological Survey since the 1950s (Wright and Schoellhamer 2004), with important implications for food web dynamics and predation. Higher water clarity is at least partially caused by increased water filtration and plankton grazing by highly abundant overbite clams (*Potamocorbula amurensis*) and other benthic organisms (Kimmerer 2004; Greene et al. 2011). High nutrient loads, coupled with reduced sediment loads and higher water clarity, could contribute to plankton and algal blooms and overall increased eutrophic conditions in some areas (Kimmerer 2004).

The first high-flow events of winter create turbid conditions in the Delta, which can be drawn into the south Delta during reverse flow conditions in the OMRs. Delta smelt may follow turbid waters into the southern Delta, increasing their proximity to project export facilities and, therefore, their entrainment risk (U.S. Fish and Wildlife Service 2008).

O.1.9.5 Contaminants

Contaminants can change ecosystem functions and productivity through numerous pathways. Trends in contaminant loadings and their ecosystem effects are not well understood, however multiple lines of evidence show contaminant effect, fate and transport, and seasonal response in contaminant loading that may be having a deleterious effect on organisms in the Dethe (Teh et al. 2020) Efforts are underway to evaluate direct and indirect toxic effects on the POD fish of manmade contaminants and natural toxins associated with blooms of Microcystis aeruginosa, a cyanobacterium or blue-green alga that releases a potent toxin known as microcystin. Toxic microcystins cause food web impacts at multiple trophic levels, and histopathological studies of fish liver tissue suggest that fish exposed to elevated concentrations of microcystins have developed liver damage and tumors (Deng et al. 2010; Acuña et al. 2012a, 2012b; Lehman et al. 2010).

There are longstanding concerns related to mercury and selenium in the Sacramento and San Joaquin watersheds, the Delta, and San Francisco Bay (see Appendix G, *Water Quality Technical Appendix*, for additional detail on these constituents). Additional study is needed to avoid increases in mercury exposure resulting from tidal wetlands restoration; methylmercury is produced at a relatively high rate in wetlands and newly flooded aquatic habitats (Davis et al. 2003). Methylmercury increases in concentration at each level in the food chain and can cause concern for people and birds that eat piscivorous fish (bass) and sturgeon (Shilling et al. 2010). It has not been shown to be a direct problem for fish in the Delta, but studies of other fish summarized by Alpers et al. (2“08) indicate that mercury in fish has been linked to hormonal and reproductive effects, liver necrosis, and altered behavior in fish. With regard to selenium, benthic foragers like diving ducks, sturgeon, and Sacramento splittail have the greatest risk of selenium toxicity; the invasion of the nonnative bivalves (e.g., *P. amurensis*) has resulted in increased bioavailability of selenium to benthivores in San Francisco Bay (Linville et al. 2“02). Spinal deformities observed in wild Sacramento splittail have been linked to selenium exposure in the habitat (Johnson et al. 2020).

Baxter et al. (2008) prepared a 2007 synthesis of results as part of a POD Progress Report, including a summary of prior studies of contaminants in the Delta. The summary included studies that suggested that phytoplankton growth rates may be inhibited by localized high concentrations of herbicides (Edmunds et al. 1999). Toxicity to invertebrates has been noted in

water and sediments from the Delta and associated watersheds (Kuivila and Foe 1995; Weston et al. 2004). The 2004 Weston study of sediment toxicity recommended additional study of the effects of the pyrethroid insecticides on benthic organisms. An updated synthesis which detailed the knowledge on known and emerging contaminants was prepared by Fong et al. (2016). An analysis by Fong et al. (2016) suggests that pyrethroids in the Delta region may be a contributor to declines in POD species. Undiluted drain water from agricultural drains in the San Joaquin River watershed can be acutely toxic (quickly lethal) to fish (Chinook salmon and striped bass) and have chronic effects on growth, likely because of high concentrations of major ions (e.g., sodium and sulfates) and trace elements (e.g., chromium, mercury, and selenium) (Saiki et al. 1992). The effects of contaminants may also vary regionally within the Delta, for example Hammock et al. (2015) found Delta smelt caught in the Cache Slough region exhibited the most sever signs of contaminant exposure.

Fish Passage and Entrainment

The Delta presents a challenge for anadromous and resident fish during upstream and downstream migration, with its complex network of channels, low eastern and southern tributary inflows, and reverse currents created by pumping for water exports. There are a large number of unscreened diversions within the Delta and while the majority of these diversions are small agricultural intake pipes, some water diversions may impact juvenile fish migration and survival. These complex conditions can lead to straying, extended exposure to predators, and entrainment during out-migration. Tidal elevations, salinity, turbidity, in-flow, meteorological conditions, season, habitat conditions, and project exports all have the potential to influence fish movement, currents, and ultimately the level of entrainment and fish passage success and survival, which is the subject of extensive research and adaptive management efforts (Independent Review Panel 2010, 2011). Michel et al. (2015) and Michel (2010) used acoustic telemetry to examine survival of late fall-run Chinook salmon smolts out-migrating from the Sacramento River through the Delta and San Francisco Estuary. Survival was lowest in the freshwater portion (Delta) and the brackish portion of the estuary relative to survival in the riverine portion of the migration route. These findings are consistent with the synthesis of salmon and steelhead survival studies by the Salmon Scoping Team (2017) and ongoing acoustic tag survival investigations.

North Delta Fish Passage and Entrainment

In the north Delta, migrating fish have multiple potential pathways as they move upstream into the Sacramento or Mokelumne river systems. Marston et al. (2012) studied stray rates for in-migrating San Joaquin River basin adult salmon that stray into the Sacramento River basin. Results indicated that it was unclear whether reduced San Joaquin River pulse flows or elevated exports caused increased stray rates. The DCC, when open, can divert fish as they out-migrate along this route. The opening of the DCC when salmon are returning to spawn to the Mokelumne and Cosumnes Rivers is believed to lead to increased straying of these fish into the American and Sacramento Rivers because of confusion over olfactory cues. Experimental DCC closures have been scheduled during the fall-run Chinook salmon migration season for selected days, coupled with pulsed flow releases from reservoirs on the Mokelumne River, in an attempt to reduce straying rates of returning adults. These closures have corresponded with reduced recoveries of Mokelumne River hatchery fish in the American River system and increased returns to the Mokelumne River hatchery (East Bay Municipal Utility District 2012).

Out-migrating juvenile fish moving down the mainstem Sacramento River also can enter the DCC when the gates are open and travel through the Delta via the Mokelumne and San Joaquin River channels. In the case of juvenile salmonids, this shifted route from the north Delta to the central Delta increases their mortality rate (Kjelson and Brandes 1989; Brandes and McLain 2001; Newman and Brandes 2010; Perry et al. 2010, 2012, 2013). Steel et al. (2013) found that the best predictor of which route was selected was the ratio of mean water velocity between the two routes. Salmon migration studies show losses of approximately 65% for groups of out-migrating fish that are diverted from the mainstem Sacramento River into the waterways of the central and southern Delta (Brandes and McLain 2001; Vogel 2004, 2008; Perry and Skalski 2008). Perry and Skalski (2008) found that, by closing the DCC gates, total through-Delta survival of marked fish to Chipps Island increased by nearly 50% for fish moving downstream in the Sacramento River system. Closing the DCC gates appears to redirect the migratory path of out-migrating fish into Sutter and Steamboat sloughs and away from Georgiana Slough, resulting in higher survival rates. Species that may be affected include juvenile green sturgeon, steelhead, and winter-run and spring-run Chinook salmon (National Marine Fisheries Service 2009a).

However, analysis by Perry et al. (2015, 2018) suggest mechanisms governing route selection are more complex. Their analysis revealed the strong influence of tidal forcing on the probability of fish entrainment into the interior Delta. The probability of entrainment into both Georgiana Slough and the DCC was highest during reverse-flow flood tides, and the probability of fish remaining in the Sacramento River was near zero during flow reversals (Perry et al. 2015). The magnitude and duration of reverse flows at this river junction decrease as inflow of the Sacramento River increases. Consequently, reduced Sacramento River inflow increases the frequency of reverse flows at this junction, thereby increasing the proportion of fish that are entrained into the interior Delta, where mortality is high (Perry 2010).

Fish passage in the north Delta also can be affected by water quality. Water quality in the mainstem Sacramento River and its distributary sloughs can be poor at times during summer, creating conditions that may stress migrating fish or even impede migration. These conditions include DO, water temperatures, and, for some species, salinity (e.g., Delta smelt). For adult Chinook salmon, DO concentration less than 3 to 5 mg/L can impede migration (Hallock et al. 1970), as can mean daily water temperatures of 70°F to 73°F depending on whether water temperatures are rising or falling (Strange 2010). Dissolved oxygen levels are generally >5 mg/L throughout the Delta, but water temperatures can exceed these thresholds during summer and fall.

The SWP Barker Slough Pumping Plant, located on a tributary to Cache Slough, may cause larval fish entrainment. The intake is equipped with a positive barrier fish screen to prevent fish at least 25 mm in size from being entrained. The CDFW has monitored entrainment of larval Delta smelt less than 20 mm at Barker Slough since 1995. When the presence of Delta smelt larvae is indicated, pumping rates from Barker Slough are reduced to a 5-day running average rate of 65 cfs, not to exceed a 75-cfs daily average for any day, for a minimum of 5 days and until monitoring shows no Delta smelt are present.

Yolo Bypass

The Fremont Weir is a major impediment to fish passage and a source of migratory delay and loss of adult Chinook salmon, steelhead, and sturgeon (National Marine Fisheries Service 2009a;

Sommer et al. 2014). Sturgeon and adult salmonids migrating upstream become concentrated in the pool behind the Fremont Weir, where they are subject to heavy legal and illegal fishing pressure. A new fish passage facility has been installed in Fremont Weir to facilitate passage of adult salmonids and sturgeon and became operational in 2018. Ongoing evaluations are being performed to determine its effectiveness. Some adult winter-run, spring-run, and fall-run Chinook salmon and white sturgeon migrate into Yolo Bypass when there is no flow into the floodplain via the Fremont Weir. Therefore, these fish are often unable to reach upstream spawning habitat in the Sacramento River and its tributaries (Harrell and Sommer 2003; Sommer et al. 2014). Other structures in the Yolo Bypass, such as the Toe Drain, Lisbon Weir, and irrigation dams in the northern end of the Tule Canal, also may impede upstream passage of adult anadromous fish (National Marine Fisheries Service 2009a).

Fish are also attracted into the bypass during periods when water is not flowing over the Fremont Weir. Fyke trap monitoring by DWR has shown that adult salmon and steelhead migrate up the Toe Drain in autumn and winter regardless of whether the Fremont Weir spills (Harrell and Sommer 2003; Sommer et al. 2014). The Toe Drain does not extend to the Fremont Weir because the channel is blocked by roads or other higher ground at several locations.

Stranding of juvenile salmonids and sturgeon has been reported in the Yolo Bypass in scoured areas behind the weir and in other areas as floodwaters recede (National Marine Fisheries Service 2009a; Sommer et al. 2005). As the Yolo Bypass flood water recedes, fish present in the floodplain are exposed to decreasing water depths and increased risk of predation by birds. However, Sommer et al. (2005) found most juvenile salmon out-migrated off the floodplain as it drained.

Central and South Delta Fish Passage and Entrainment

Diversion facilities in the south Delta include the CVP and SWP export facilities; local agency intakes, including Contra Costa Water District (CCWD) intakes; and agricultural intakes. CCWD intakes, including the CVP Contra Costa Canal Rock Slough Intake, have fish screens; however, most of the remaining intakes do not include fish screens. Water flow patterns in the south Delta are influenced by the water diversion actions and operations of the south Delta seasonal temporary barriers and tides and river inflows to the Delta (Kimmerer and Nobriga 2008). Delta diversions can create tidally averaged reverse flows, drawing fish toward project facilities if they are within the footprint of altered hydrology (Arthur et al. 1996; Kimmerer 2008; Grimaldo et al. 2009); though recent investigations have determined that altered channel velocities and flow direction are more likely to influence juvenile salmonids than tidally averaged net flow conditions (Anderson et al. 2012; Monismith et al. 2014; Salmonid Scoping Team 2017). While swimming through southern Delta channels, fish can be subjected to stress from poor water quality (seasonally high temperatures, low DO, high water transparency, and Microcystis blooms) and slow water velocities in lake-like habitats. Any of these factors can cause elevated mortality rates by weakening or disorienting the fish and increasing their vulnerability to predators (Vogel 2011a). Analyses have identified regions of mortality hot spots for juvenile salmon in the South and Central Delta (Salmonid Scoping Team 2017; Grossman 2016) which may relate to one or more of these mechanisms.

Cunningham et al. (2015) conducted a statistical analysis of adult Chinook spawning escapement from 1967 to 2010 and found a negative correlation of the export/inflow (I:E) ratio on the survival of fall-run Chinook salmon populations and a negative correlation of increased total Delta exports on the survival of spring-run Chinook populations. According to the Cunningham et al. results, an increase in total exports of 1 standard deviation from the 1967 to 2010 average was predicted to result in a 68.1% reduction in the survival of Deer, Mill, and Butte Creek spring-run Chinook salmon. Similarly, an increase in the ratio of Delta water exports to Delta inflow of 1 standard deviation was expected to reduce survival of the four fall-run populations by 57.8% (Cunningham et al. 2015). However, these results are based on correlations between indices of export operations and spawning escapement observed over more than 40 years, and thus may reflect changes through time in factors not included in the statistical analysis. The magnitude of export effects predicted by Cunningham et al. (2015) are inconsistent with direct empirical evaluations of Delta juvenile salmon survival relative to export rates that have shown smaller magnitude and more uncertain effects (Newman 2003; Newman and Brandes 2010; Newman 2008; Zeug and Cavallo 2013; Salmonid Scoping Team 2017). Although a mechanistic explanation for the large predicted export-survival effect remains elusive, Cunningham et al. (2015) state, "*direct entrainment mortality seems an unlikely mechanism given the success of reclamation and transport procedures, even given increased predation potential at the release site. Changes to water routing may provide a more reasonable explanation for the estimated survival influence of Delta water exports*". However, hydrodynamic analysis suggest exports have minimal potential to influence routing at junctions of the North and Central Delta (Cavallo et al. 2015) and are therefore unlikely to provide a plausible mechanism for the effect.

Delaney et al. (2014) reported on a mark-recapture experiment examining the survival and movement patterns of acoustically tagged juvenile steelhead emigrating through the central and southern Delta. Their results indicated that most tagged steelhead remained in the mainstem San Joaquin River (77.6%); however, approximately one quarter (22.4%) of them entered Turner Cut. Route-specific survival probability for tagged steelhead using the Turner Cut route was 27.0%. The survival probability for tagged steelhead using the Mainstem route was 56.7% (Delaney et al. 2014). Travel times for tagged steelhead also differed between these two routes, with steelhead using the mainstem route reaching Chipps Island significantly sooner than those that used the Turner Cut route. Travel time was not significantly affected by the limited OMR flow treatments examined in their study. While not significant, there was some evidence that fish movement toward each export facility could be influenced by relative flow entering the export facility (Delaney et al. 2014).

Water from the San Joaquin River mainly moves downstream through the HOR and through the channels of OMRs and Grant Line and Fabian-Bell canals toward the south Delta intake facilities. Conversely, when water to the north of the diversion points for the two facilities moves southward (upstream), the net flow is negative and toward the pumps. When the temporary barriers are installed from April through November, internal reverse circulation is created within the channels isolated by the barriers from other portions of the south Delta. These conditions are most pronounced during late spring through fall when San Joaquin River inflows are low and water diversion rates are typically high. Drier hydrologic years also reduce the frequency of net downstream flows in the south Delta and mainstem San Joaquin River.

A portion of fish that enter the CVP Jones Pumping Plant approach channel and the SWP Clifton Court Forebay are salvaged at screening and fish salvage facilities, transported downstream by trucks, and released. NMFS (2009) estimated that the loss of fish from the screening and salvage process is in the range of 65 to 83.5% for fish from the point they enter Clifton Court Forebay or encounter the trash racks at the CVP facilities. Loss occurs due to sources of mortality during the salvage, collection, handling, and transport phases (Jahn and Kier 2020, Karp et al 2017, Raquel et al 1989). Mark-recapture experiments indicate that most fish are probably subject to predation prior to reaching the fish salvage facilities (e.g., in Clifton Court Forebay) (Gingras 1997; Clark et al. 2008; Castillo et al. 2012). Fish entrainment and salvage are particular concerns during dry years when the distributions of young striped bass, Delta smelt, longfin smelt, and other migratory fish species shift closer to the project facilities (Stevens et al. 1985; Sommer et al. 1997). Aquatic organisms (e.g., phytoplankton and zooplankton) that serve as food for fish also are entrained and removed from the Delta (Jassby et al. 2002; Kimmerer et al. 2008; Brown et al. 1996).

Salvage estimates reflect the number of fish entrained by project exports, but these numbers alone do not account for other sources of mortality related to the export facilities. These numbers may not include prescreen losses that occur in the waterways leading to the diversion facilities, which may in some cases reduce the number of salvageable fish (Gingras 1997; Clark et al. 2008; Castillo et al. 2012). For Delta smelt, prescreen losses appear to be where most mortality occurs (Castillo et al. 2012). In addition, actual salvage numbers do not include the entrainment of fish larvae, which cannot be collected by the fish screens. The number of fish salvaged also does not include losses of fish that pass through the louvers intended to guide fish into the fish collection facilities or the losses during collection, handling, transport, and release back into the Delta.

Recent publications are available that provide an overview of general findings relevant to tidal Delta. Perry et al. (2018) utilized nearly 3,000 acoustically tagged fish released into the North Delta. Among other important findings, he reported survival in tidal reaches of the Delta were not related to river inflows (exports effects were not evaluated). Buchanan et al. (2018) reports on 6 years of studies including 8,000 acoustically tagged juvenile Chinook salmon released into the San Joaquin River Delta. In all years, through-Delta survival was extremely low, ranging from 0 to 5%. Very high San Joaquin River inflows improved survival in riverine reaches, but survival in tidal areas of the Delta remained low despite ostensibly favorable tidally averaged flow conditions. In 2010 and 2011, relatively wet years when no HOR Barrier was installed, acoustically tagged salmon having passed through the Old River and Granite Line Canal corridor and continuing to head north in the OMR corridor experienced extremely low survival despite positive tidally averaged flow conditions. Importantly, juvenile salmon entrained into the CVP export facilities during these studies experienced higher survival to Delta exit than fish migrating volitionally northward in the OMR corridor. In 2010 and 2011, an average of 64% of the tagged juvenile salmon surviving to exit the Delta were fish entrained, salvaged and trucked from the CVP export facilities. The remaining 34% that survived to Delta exit appear to have migrated volitionally through the San Joaquin River portion of the Delta (i.e., not through the OMR route). Were it not for the placement of the HOR Barrier in 2012 through 2016, more observations would be available to understand the apparently positive contribution of CVP export salvage to through-Delta survival.

Buchanan et al. (2021) reports survival and travel time of studies including tagged juvenile steelhead released into the San Joaquin River Delta. Survival and travel time of juveniles emigrating from the San Joaquin River through the Delta were highly variable both among years and among release groups within each year. Travel time from HOR to Chipps Island ranged from 1.4 to 34.9 days. Survival from HOR to Chipps Island via the San Joaquin River ranged from 0 to 0.72 and via Old River ranged from 0.05 to 0.72.

The Salmonid Scoping Team (2017) reported juvenile Chinook salmon survival relative to the 10-day average of total exports and San Joaquin River inflows. No negative association with exports was apparent, though relatively few observations were available at high export rates. A similar 6-year study utilizing steelhead smolts (rather than juvenile Chinook salmon) has been completed, but is not yet fully reported. Results available indicate higher survival rates for steelhead smolts relative to juvenile Chinook salmon, but a similar absence of negative response to exports.

Analysis of 14 years of coded wire tag Chinook salmon releases (representing more than 28 million coded wire tagged juvenile salmon) in the Sacramento and San Joaquin rivers were performed by Zeug and Cavallo (2014) to estimate proportional entrainment losses and to elucidate conditions that result in salvage of migrating fish. They compared the capability of an E:I ratio relative to separate flow and export values to explain the data and found the ratio was not an effective predictor. Further, the authors reported weak and inconsistent effects of flow on salvage whereas export effects were relatively strong. Their findings suggest that flow and exports are not interchangeable components as is sometimes assumed. Zeug and Cavallo (2014) also found entrainment loss (salvage of fish expanded for subsampling and pre-screen mortality) was very low (mean 0.1% across all races and releases) and contributed little to through-Delta migration mortality.

To evaluate the hypothesized effect of export operations pulling migrating juvenile salmon into the South Delta, Cavallo et al. (2015) analyzed 41 independent estimates of junction routing probabilities derived from several different juvenile salmon acoustic telemetry studies. The analysis found that routing at the HOR junction was influenced by exports, but only with lowest levels of San Joaquin River inflow. South Delta exports exhibited no substantive influence on fish routing at any other analyzed junction in the Delta.

A study of salmonid behavior and TFCF efficiency at the CVP was performed in 2013 using acoustic telemetry (Karp et al. 2017). Findings indicate salmon are more likely to enter the CVP export facility at high-pumping rates. Lower pumping rates resulted in salmon spending more time in areas where they are exposed to predators. This suggests that reducing pumping levels when fish are detected at the export facility may reduce salvage, but fish already near the facilities may be preyed upon rather than entering the facility and then being salvaged. The Karp et al. (2017) findings provide an explanatory mechanism for patterns revealed by coded wire tag survival studies (Newman 2008) by more recent acoustic tagging studies Buchanan et al. (2018) where salvage at the CVP appears to provide higher probability of through-Delta survival than natural migration.

The life stage of the fish at which entrainment occurs may be important for population dynamics (Independent Review Panel 2011). For example, winter entrainment of Delta smelt and longfin smelt may correspond to migration and spawning of adult fish, and spring and summer exports may overlap with development of larvae and juveniles. The loss of pre-spawning adults and all their potential progeny may have greater consequences than entrainment of the same number of larvae or juvenile fish. Entrainment risk for fish tends to increase with increased OMR reverse flows (Kimmerer 2008; Grimaldo et al. 2009; Smith et al. 2021).

There are more than 2,200 diversions in the Delta (Herren and Kawasaki 2001). These irrigation diversion pipes are shore-based, typically small (30 to 60 cm pipe diameter), and operated via pumps or gravity flow, and most lack fish screens. These diversions increase total fish entrainment and losses and alter local fish movement patterns (Kimmerer and Nobriga 2008). Delta smelt have been found in samples of Delta irrigation diversions, as well as larger wetland management diversions downstream. A study by Nobriga et al. (2004) found that the low and inconsistent entrainment of Delta smelt reflected the offshore distribution of Delta smelt and the relatively small hydrodynamic influence of the diversion facility. The Nobriga et al. (2004) paper is a single study on the impacts of one diversion facility on Delta smelt and the impacts of other diversions in the Delta are not being discounted based on this one study.

Suisun Bay and Marsh

Several facilities have been constructed by DWR and Reclamation to provide lower-salinity water to managed wetlands in the Suisun Marsh, including the Roaring River Distribution System, Morrow Island Distribution System, Goodyear Slough Outfall, and the Suisun Marsh Salinity Control Gates (SMSCG). Other facilities constructed under the Suisun Marsh Preservation Agreement that could entrain fish include the Lower Joice Island and Cygnus Drain diversions.

The intake to the Roaring River Distribution System is screened to prevent entrainment of fish larger than approximately 1 inch (approximately 25 mm). DWR monitored fish entrainment from September 2004 to June 2006 at the Morrow Island Distribution System to evaluate entrainment losses at the facility. Monitoring took place over several months under various operational configurations and focused on Delta smelt and salmonids. Over 20 species were identified during the sampling, but only two fall-run-sized Chinook salmon (at the South Intake in 2006) and no Delta smelt from entrained water were sampled (Bureau of Reclamation 2008). The Goodyear Slough Outfall system is open for free fish movement except near the outfall when flap gates are closed during flood tides (Bureau of Reclamation 2008). Conical fish screen have been installed on the Lower Joice Island diversion on Montezuma Slough.

A study was conducted in the fall of 2001-2004 to assess the success of passage of fall-run Chinook salmon during different configurations at the SMSCG (Vincik 2012). Approximately 200 adult fall-run were ultrasonically tagged and three configurations were tested. The results of the study indicated that the open boat lock configuration, relative to the closed configuration, was correlated with improved passage rates in 2 out of 4 years but that passage time was variable across years.

O.1.9.6 Disease

Preliminary results of several histopathological studies have found evidence of significant disease in Delta fish species (Bureau of Reclamation 2008). For example, massive intestinal infections with an unidentified myxosporean were found in yellowfin goby collected from Suisun Marsh (Baxa et al. 2013). Studies (Bennett 2005; Bennett et al. 2008; Hammock et al. 2015) show that exposure to toxic chemicals may cause liver abnormalities and cancerous cells in Delta smelt, and stressful summer conditions, warm water, and lack of food may result in liver glycogen depletion and liver damage. Studies of Sacramento splittail suggest that liver abnormalities in this species are more linked to health and nutritional status than to pollutant exposure (Greenfield et al. 2008).

Additionally, preliminary evidence suggests that contaminants and disease may impair striped bass. Studies by Lehman et al. (2010) suggest that the liver tissue and health of striped bass and inland silverside were adversely affected by tumor-promoting substances, particularly at sampling stations where concentrations of tumor-promoting microcystins were elevated. Exposure of Sacramento splittail and threadfin shad to microcystins in experimental diets resulted in severe liver damage; shad also exhibited ovarian necrosis, indicating impairment of health and reproductive potential (Acuña et al. 2012a).

In contrast, histopathological and viral evaluation of juvenile longfin smelt and threadfin shad collected in 2006 indicated no histological abnormalities and no evidence of viral infections or high parasite loads (Foott et al. 2006). Parasites were noted in threadfin shad gills at a high frequency, but the infections were not considered severe. Thus, both longfin smelt and threadfin shad were considered healthy in 2006 (a high-flow year). Adult Delta smelt collected from the Delta during winter 2005 also were considered healthy, showing little histopathological evidence for starvation or disease (Bureau of Reclamation 2008). However, there was some evidence of low frequency endocrine disruption. In 2005, 9 of 144 (6%) adult Delta smelt males were intersex, having immature oocytes in their testes (Bureau of Reclamation 2008).

O.1.9.7 Nonnative Invasive Species

Nonnative invasive species influence the Delta ecosystem by increasing competition and predation on native species, reducing habitat quality (as result of invasive aquatic macrophyte growth), and reducing food supplies by altering the aquatic food web. Not all nonnative species are considered invasive.[4] Some introduced species have minimal ability to spread or increase in abundance. Others have commercial or recreational value (e.g., striped bass, American shad, and largemouth bass).

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[4] CDFG (2008) defines invasive species as "species that establish and reproduce rapidly outside of their native range and may threaten the diversity or abundance of native species through competition for resources, predation, parasitism, hybridization with native populations, introduction of pathogens, or physical or chemical alteration of the invaded habitat."

Many nonnative fish have been introduced into the Delta for sport fishing (game fish such as striped bass, largemouth bass, smallmouth bass, bluegill, and other sunfish), as forage for game fish (threadfin shad, golden shiner, and fathead minnow), for vector control (inland silverside, Western mosquitofish), for human food use (common carp, brown bullhead, and white catfish), and from accidental releases (Yellowfin Goby, Shimofuri goby, and Shokihaze goby) (Moyle 2002). Introduced fish may compete with native fish for resources and, in some cases, prey on native species.

Because of invasive species and other environmental stressors, native fish have declined in abundance throughout the region during the period of monitoring (Matern et al. 2002; Brown and Michniuk 2007; Sommer et al. 2007a; Mount et al. 2012). Habitat degradation, changes in hydrology and water quality, and stabilization of natural environmental variability are all factors that generally favor nonnative, invasive species (Mount et al. 2012; Moyle et al. 2012).

The lower trophic food web has also undergone extensive alterations due to nonnative invasive species, the most prominent being the invasion and establishment of *P. amurensis* in Suisun Bay which has reduced phytoplankton, microzooplankton, copepod and mysid shrimp abundances likely resulting in decreased fish abundance (Feyrer et al. 2007; Kimmerer 2002b, Winder and Jassby 2011; Kayfetz and Kimmerer 2017; Hammock et al. 2019). Other invasive zooplankton species such as *P. forbesi* have replaced previously abundant species such as *Eurytemora affinis*. In addition to the effect of *P. amurensis* on the *P. forbesi*, the invasion of the predatory copepod *A. sinensis* likely further reduced the range of *P. forbesi* landward (Kayfetz and Kimmerer 2017; Slaughter et al. 2016). The native mysid *N. mercedis* was replaced by the nonnative *H. longirostris*, which may be a less nutritious prey item for fish due to their smaller size (Avila and Hartman 2020).

Invasive aquatic macrophytes are still equilibrating within the Delta and resulting habitat changes are ongoing, with negative impacts on habitats and food webs of native fish species (Toft et al. 2003; Grimaldo et al. 2009). Concerns about invasive aquatic macrophytes are centered on their ability to form large, dense growth that can clog waterways, block fish passage, increase water clarity, provide cover for predatory fish, and cause high biological oxygen demand.

The introduction of two nonnative invasive aquatic plants, water hyacinth and Brazilian waterweed, has reduced habitat quantity and value for many native fish. Water hyacinth forms floating mats that greatly reduce light penetration into the water column, which can significantly reduce primary productivity and available food for fish in the underlying water column. Brazilian waterweed grows along the margins of channels in dense stands that prohibit access by native juvenile fish to shallow water habitat. Additionally, the thick cover of these two invasive plants provides excellent habitat for nonnative ambush predators, such as bass, which prey on native fish species (Ferrari et al. 2014). The ongoing Division of Boating and Waterways control efforts may improve fish habitat quality. Studies indicate low abundance of native fish, such as Delta smelt, Chinook salmon, and Sacramento splittail, in areas of the Delta where submerged aquatic vegetation infestations are thick (Grimaldo et al. 2004, 2012; Nobriga et al. 2005).

O.1.9.8 Predation

Predation is an important factor that influences the behavior, distribution, and abundance of prey species in aquatic communities to varying degrees. Predation can have differing effects on a population of fish depending on the size or age selectivity, mode of capture, mortality rates, and other factors. Predation is a part of every food web, and native Bay-Delta fish were part of the historical Bay-Delta food web. Because of the magnitude of change in the Bay-Delta from historical times and the introduction of nonnative species (e.g. striped bass, black basses), it is logical to conclude that predation may have increased in importance as a mortality factor for Bay-Delta fish, with some observers suggesting that it is likely the primary source of mortality for juvenile salmonids in the Delta (Vogel 2011b). Predation occurs by fish, birds, and mammals, including sea lions. The alternatives considered in this EIS are not anticipated to modify predatory actions of birds and mammals on the focal species. Therefore, the predation discussion is focused on fish predators.

A panel of Bay-Delta salmonid experts was charged with evaluating a series of pre-assigned papers and convened to review data on predation in the Delta and draw preliminary conclusions on the effects of predation on salmonids. The panel acknowledged that the system supports large populations of fish predators that consume juvenile salmonids (Grossman et al. 2013). However, the panel concluded that because of extensive flow modification, altered habitat conditions, native and nonnative fish and avian predators, temperature and DO limitations, and the overall reduction in salmon population size, it was unclear what proportion of the juvenile salmonid mortality could be attributed to predation. The panel further indicated that predation, while the proximate cause of mortality, may be influenced by a combination of other stressors that make fish more vulnerable to predation.

Striped bass, white catfish, channel catfish, largemouth bass and other centrarchids, and inland silverside are among the introduced, nonnative species that are notable predators of smaller-bodied fish species and juveniles of larger species in the Bay-Delta. Largemouth bass, striped bass, white catfish, and channel catfish are believed to be major predators on larger-bodied fish in the Bay-Delta. In open-water habitats, striped bass are most likely the primary predator of juvenile and adult Delta smelt (California Department of Water Resources et al. 2013) and can be an important open-water predator on juvenile salmonids (Johnston and Kumagai 2012). Native Sacramento pikeminnow may also prey on juvenile salmonids and other fish. Limited sampling of smaller pikeminnows did not find evidence of salmonids in the foregut of Sacramento pikeminnow (Nobriga and Feyrer 2007), but this does not mean that Sacramento pikeminnow do not prey on salmonids in the Delta.

Largemouth bass abundance has increased in the Delta over the past few decades (Brown and Michniuk 2007). Although largemouth bass are not pelagic, their presence at the boundary between the littoral and pelagic zones makes it probable that they opportunistically consume pelagic fish. The increase in salvage of largemouth bass occurred during the time period when Brazilian waterweed was expanding its range in the Delta (Brown and Michniuk 2007). The beds of Brazilian waterweed provide good habitat for largemouth bass and other centrarchids. Largemouth bass have a much more limited distribution in the estuary than striped bass, but a higher per-capita impact on small fish (Nobriga and Feyrer 2007). Increases in largemouth bass may have had a particularly important effect on threadfin shad and striped bass, whose earlier life stages occur in littoral habitat (Grimaldo et al. 2004; Nobriga and Feyrer 2007).

Invasive inland silversides are another potentially important predator of larval and pelagic fish in the Delta. This introduced species was not believed to be an important predator on Delta smelt, but studies using DNA techniques detected the presence of Delta smelt in the guts of inland silversides (Baerwald et al. 2012; Schreier et al. 2016). This finding may suggest that predation impacts could be significant, given the increasing numbers of inland silversides in the Delta.

Predation of fish in the Delta is known to occur in specific areas such as channel junctions and areas that constrict flow or confuse migrating fish and provide cover for predatory fish (Vogel 2011b). Analyses from predation studies through FISHBIO have identified regions of mortality hot spots for juvenile salmon in the South and Central Delta (Grossman et al. 2013; Grossman 2016). Sabal (2014) found similar results through collaboration with EBMUD at Woodbridge Dam on the Mokelumne River where the dam was associated with increased striped bass per capita salmon consumption and attracted larger numbers of striped bass, decreasing migrating juvenile salmon survival by 10% to 29%. The California Department of Fish and Game (1992) identified subadult striped bass as the major predatory fish in Clifton Court Forebay. In 1993, for example, striped bass made up 96% of the predators removed (Vogel 2011a). Predation in Clifton Court Forebay occurs on salmonids and Delta smelt alike (Castillo et al. 2012). Cavallo et al. (2012) studied tagged salmon smolts to test the effects of predator removal on out-migrating juvenile Chinook salmon in the south Delta. Their results suggested that predator abundance and migration rates strongly influenced survival of salmon smolts. Exposure time to predators has been found to be important for influencing survival of out-migrating salmon in other studies in the Delta (Perry et al. 2012). Predation in the Bay-Delta has also been found to be influenced by environmental conditions including habitat and temperatures, which can result in predation "hot-spots" (Hayes et al 2017, Michel et al 2021, Michel et al 2020a,b). Understanding these relationships between the Delta environment and predation explain why past survival studies have shown a substantial amount of tagged juvenile salmonid may have been predated on and these detections reflect predator movements (Vogel 2011b). A predator filter used by Buchanan et al. (2021) removed 7 – 14% of annual detection events (tagged fish were released 2011 – 2016).

O.1.9.9 Aquatic Macrophytes

Aquatic macrophytes are an important component of the biotic community of Delta wetlands and can provide habitat for aquatic species, serve as food, produce detritus, and influence water quality through nutrient cycling and DO fluctuations. Whipple et al. (2012) described likely historical conditions in the Delta, which have been modified extensively, with major impacts on the aquatic macrophyte community composition and distribution. The primary change has been a shift from a high percentage of emergent aquatic macrophyte wetlands to open water and hardened channels.

O.1.10 San Francisco Bay Area

Fish and aquatic habitat resources in the San Francisco Bay Area include habitat through San Francisco Bay. The San Francisco Bay Area also includes fish habitat within reservoirs that store CVP and SWP water. CVP and SWP water supplies are stored in Contra Loma and San Justo Reservoirs; the SWP Bethany Reservoir and Lake Del Valle; the CCWD Los Vaqueros Reservoir; and the East Bay Municipal Utility District (EBMUD) Upper San Leandro, San Pablo, Briones, and Lafayette reservoirs and Lake Chabot. Many of these reservoirs also store water from local and regional water supplies.

O.1.10.1 Contra Loma Reservoir

Contra Loma Reservoir is a CVP facility in Contra Costa County that provides offstream storage along the Contra Costa Canal. The 80-acre reservoir is part of 661-acre Contra Loma Regional Park and Antioch Community Park (Bureau of Reclamation 2014b). There are currently 20 known fish species, including 8 species of game fish, in Contra Loma Reservoir. The East Bay Parks and Recreation District and CDFW stock rainbow trout and channel catfish in the reservoir. The reservoir also supports self-sustaining populations of largemouth bass, crappie, redear sunfish, and bluegill, which are also popular with anglers (Bureau of Reclamation 2014b). Other species found include white catfish, threadfin shad, bigscale logperch, common carp, Sacramento blackfish, warmouth, green sunfish, goldfish, prickly sculpin, and inland silversides (Bureau of Reclamation 2014b).

Some of the fish species present have been introduced from the Delta via the Contra Costa Canal. In 2011, the Rock Slough Fish Screen at the head of Contra Costa Canal was constructed to prevent the entrainment of federally protected species such as Delta smelt at the Rock Slough Intake of the Contra Costa Canal. The screen also minimizes fish entrainment and significantly reduces the potential for fish introductions into Contra Loma Reservoir from the Contra Costa Canal (Bureau of Reclamation 2014b).

O.1.10.2 San Justo Reservoir

The San Justo Reservoir is a CVP facility in San Benito County that provides offstream storage as part of the San Felipe Division. Other than stocked rainbow trout, all of the fish and other aquatic organisms that have been observed in San Justo Reservoir are nonnative species (San Benito County Water District 2012).

O.1.10.3 South Bay Aqueduct Reservoirs

Bethany Reservoir, Patterson Reservoir, and Lake Del Valle are SWP facilities associated with the South Bay Aqueduct in Alameda County. At Bethany Reservoir, anglers catch five types of bass (spotted, white, largemouth, smallmouth, and striped bass), crappie, catfish, and trout (California State Parks 2020). Presumably, many of the same species would be found in Patterson Reservoir. Lake Del Valle is stocked regularly with trout and catfish. largemouth bass, smallmouth bass, striped bass, and panfish are also caught (East Bay Parks and Recreation District 2014).

O.1.10.4 Los Vaqueros Reservoir

Los Vaqueros Reservoir is a CCWD offstream storage facility in Contra Costa County. Aquatic habitat quality for fish is low to moderate due to poorly developed cover vegetation along the shoreline. The reservoir has a robust recreational fish stocking program, primarily rainbow trout. Gamefish at the reservoir include rainbow trout, Kokanee, largemouth bass, brown bullhead, catfish, striped bass, sunfish, white crappie, and Sacramento perch (Contra Costa Water District 2019).

O.1.10.5 East Bay Municipal Utility District Reservoirs

EBMUD reservoirs in Alameda and Contra Costa County used to store water within and near the EBMUD service area include Briones Reservoir, San Pablo Reservoir, Lafayette Reservoir, Upper San Leandro Reservoir, and Lake Chabot. Water stored in these reservoirs includes water

from local watersheds, the Mokelumne River watershed, and CVP water supplies. San Pablo Reservoir is regularly stocked with trout and catfish (East Bay Municipal Utility District 2014). Other species caught in the reservoir include crappie, largemouth bass, smallmouth bass, spotted bass, and common carp (Office of Environmental Health Hazard Assessment 2009).

The CDFW annually stocks trout in Lafayette Reservoir. Other species found in the reservoir include bluegill, black basses, black crappie, and several species of catfish (Lafayette Chamber of Commerce 2014).

Lake Chabot is stocked with hatchery-raised rainbow trout and channel catfish by the East Bay Parks and Recreation District and CDFW for recreational fishing. The lake also supports a popular nonnative, warm water recreational fishery for largemouth bass, bluegill, and black crappie. Some native trout escape from the Upper San Leandro Reservoir during spill events and likely end up in Lake Chabot (East Bay Municipal Utility District 2013).

O.1.11 CVP and SWP Service Areas (south to Diamond Valley)

O.1.11.1 San Luis Reservoir

San Luis Reservoir is located at the base of the foothills on the west side of the San Joaquin Valley in Merced County. Water from the Delta is delivered to San Luis Reservoir via the California Aqueduct and Delta-Mendota Canal for storage.

San Luis Reservoir and O'Neill Forebay support several species of fish that have become established within the system, either by direct introduction or from the Delta system via pumping from the California Aqueduct and Delta-Mendota Canal (DMC). Striped bass are the predominant species in San Luis Reservoir (California Department of Water Resources 1987) and support a recreational fishery. Other species include Sacramento blackfish, American shad, threadfin shad, largemouth bass, Kokanee salmon, green sunfish, bluegill, white sturgeon, and white crappie.

There are no sensitive fish species in the San Luis Reservoir except, possibly, individuals entrained by the CVP and SWP projects in the Delta. These individuals have already been lost to their populations, as they cannot return to the Delta once entrained. Potentially occurring fish species with special status that may have been imported from the Delta include Chinook salmon, Delta smelt, hardhead, white sturgeon, and Sacramento splittail (Bureau of Reclamation and California Department of Parks and Recreation 2013).

O.1.11.2 Delta Mendota Canal and California Aqueduct Intertie

The C.W. Bill Jones Pumping Plant and the Harvey O. Banks Pumping Plant lift water into the DMC. CVP water is conveyed in the DMC for direct diversion or for delivery to San Luis Reservoir. Water from the San Luis Reservoir is also conveyed through the San Luis Canal and Pacheco Tunnel. The DMC–California Aqueduct Intertie connects the CVP and SWP conveyance facilities after export from the Delta. Fishing access is provided at 16 designated fishing sites along the Aqueduct and California Department of Fish and Wildlife's fishing regulations apply throughout the SWP.

O.1.11.3 Southern California

Portions of Ventura, Los Angeles, Orange, San Diego, Riverside, and San Bernardino Counties are served by the SWP. There are six SWP reservoirs along the main canal, West Branch, and East Branch of the California Aqueduct and many other reservoirs owned and operated by regional and local agencies. The Metropolitan Water District of Southern California's Diamond Valley Lake and Lake Skinner primarily store water from the SWP. Other reservoirs store SWP water, including United Water Conservation District's Lake Piru; the city of Escondido's Dixon Lake; San Diego's San Vicente Reservoir and Lower Otay Reservoir; Helix Water District's Lake Jennings; and Sweetwater Authority's Sweetwater Reservoir.

State Water Project Reservoirs

SWP reservoirs include Quail Lake, Pyramid Lake, and Castaic Lake in Los Angeles County; Silverwood Lake and Crafton Hills Reservoir in San Bernardino County; and Lake Perris in Riverside County.

Although small compared to nearby Pyramid and Castaic lakes, Quail Lake's 290 acres provide 3 miles of shoreline fishing. striped bass, channel catfish, Sacramento blackfish, tule perch, threadfin shad, and hitch have been found at Quail Lake (California Department of Water Resources 1997).

Pyramid Lake is in the Angeles and Los Padres National Forests, about 60 miles northwest of downtown Los Angeles. Largemouth bass, smallmouth bass, striped bass, bluegill, crappie, brown bullhead, channel catfish, and trout are caught by anglers in Pyramid Lake (Office of Environmental Health Hazard Assessment 2013a). Rainbow trout, bluegill, green sunfish, largemouth bass, catfish, and prickly sculpin are found in Piru Creek below the dam (California Department of Water Resources 2005b).

Castaic Lake supports a warm water fishery for striped bass, largemouth bass, and bluegill. Cyprinids and bluegill provide a strong forage base for both bass fisheries in addition to being caught by anglers. The CDFW maintains a rainbow trout fishery in Castaic Lake through stocking (California Department of Water Resources 2007).

Silverwood Lake is in the San Bernardino National Forest and surrounded by the Silverwood Lake State Recreation Area at the edge of the Mojave Desert and at the base of the San Bernardino Mountains. Common sport fish caught in Silverwood Lake include stocked rainbow trout, largemouth bass, bluegill, common carp, crappie, catfish, and striped bass (California State Parks 2009; Office of Environmental Health Hazard Assessment 2013b). Other species found in the lake include Sacramento blackfish, brown bullhead, tui chub, and tule perch (Office of Environmental Health Hazard Assessment 2013b).

The Crafton Hills Reservoir area includes 4.5 acres of open water and 1.9 acres of open space. One fish species, mosquitofish, was observed in the reservoir (California Department of Water Resources 2009).

Lake Perris is located within the Lake Perris State Recreation Area, which provides extensive recreational opportunities. Lake Perris is stocked with rainbow trout and managed as a recreational fishery. Common fish species in the lake include largemouth bass, channel catfish, bluegill, spotted bass, flathead catfish, green sunfish, redear sunfish, and black crappie (California Department of Water Resources 2010). Other species found in the lake include inland silverside and threadfin shad (California Department of Water Resources 2007).

O.1.12 Nearshore Pacific Ocean Habitat of Southern Resident Killer Whale

Anadromous fish species use the Pacific Ocean as part of their life cycles. In addition, the Pacific Ocean supports the Southern Residents DPS, which relies on large anadromous fish in the ocean, particularly Chinook salmon, as their preferred prey.

O.1.12.1 Pacific Ocean Habitat of the Killer Whale

The Pacific Ocean along the coast of California is included in this description of the affected environment because it provides habitat for the Southern Residents' population. The effect of the action, however, is limited to potential changes in the number of Chinook salmon produced in the Central Valley and Trinity River regions entering the Pacific Ocean which may contribute an important component of the Southern Residents diet.

The Southern Residents are known to occur frequently in the inland waters of Washington, USA, and British Columbia, Canada also known as the Salish Sea (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound), the outer coastal waters (within ~50 km of shore) from Haida Gwaii, Canada down the West coast of Vancouver Island, Washington, Oregon, and California as far south as Monterey Bay (National Marine Fisheries Service 2021b).

NMFS first listed the Southern Residents DPS as endangered on November 18, 2005 (70 FR 69903) and reaffirmed as endangered on August 5, 2013 (78 FR 47277, National Marine Fisheries Service 2021b). NMFS designated critical habitat for the Southern Residents DPS in inland waters of Washington State on November 29, 2006 (71 FR 69054). NMFS revised the critical habitat area to include six additional coastal critical habitat areas along the U.S. West Coast on August 2, 2021 (86 FR 41668) and completed a thorough review of scientific information to date relevant to critical habitat (National Marine Fisheries Service 2021c).

The 2006 designated critical habitat consisted of three areas: (1) The Summer Core Area in Haro Strait and waters around the San Juan Islands, (2) the Puget Sound Area, and (3) the Strait of Juan de Fuca Area (71 FR 69054). The 2021 critical habitat revision added coastal waters between the 6.1 meter and 200 meter depth contours off the coast of Washington, Oregon, and California from the U.S. international border with Canada south to Point Sur, California (86 FR 41668).

NMFS's 2008 *Recovery Plan for Southern Resident Killer Whales* defines potential threats to the Southern Residents population (National Marine Fisheries Service 2008). The major threats are suspected to be prey availability, pollution and contamination, vessel effects, oil spills, and acoustic effects. The most recent five-year review came out in 2021 and determined that new information increases our knowledge of Southern Residents conditions and threats, but it does not indicate a change to the species' status or the magnitude or imminence of the threats since the listing. More recent studies (Lacy et al. 2017; Murray et al. 2021) have focused on finding

correlation between threat and population. Lacey et al. 2017), found prey availability had the largest impact and suggested prey increase in combination with reduced acoustic disturbance could help reach the targeted growth rate. Murray et al. (2021) did not suggest one threat to be more impactful than the other. However, of all the threats described for the SRKW, in the Pacific Ocean, the long term operations of the CVP and SWP could only change prey availability and would not change any of the other identified threats. Southern resident killer whales forage on fish. Chinook salmon are their preferred prey (Ford and Ellis 2005); however, they will eat other salmonids, some groundfish, and, rarely, other types of fish and cephalopods (Hanson et al. 2021). They tend to diversify their diet more in the wintertime to include steelhead, chum, lingcod and halibut but Chinook salmon remain their preferred prey when available (Hanson et al. 2021). Fall-run and Spring-run Chinook salmon that originate from the Central Valley of California and the Trinity River make up some of the prey consumed by southern resident killer whales (Hanson et al. 2021) with a higher proportion of Central Valley Chinook salmon (19%) identified in prey samples collected in outer coastal waters and a smaller proportion of Central Valley Chinook (<5%) identified in prey samples collected in Puget Sound. This is consistent with studies that show Chinook salmon of Central Valley and Trinity River origin can occur as far north as the coastal waters off British Columbia during their ocean-going life-history phase; however, the majority of the Central Valley Chinook salmon do not travel further north than the border of California and Oregon (Weitkamp 2009; Shelton et al. 2019).

There are multiple lines of evidence of poor body condition in Southern Residents (Durban et al. 2009; Fearnbach et al. 2011; Matkin et al. 2017; Fearnbach et al. 2018; Fearnbach et al. 2020) and how the Southern Residents may be affected by limitations of their primary prey, Chinook salmon (Ward et al. 2009; Ayres et al. 2012; National Marine Fisheries Service 2016b; Wasser et al. 2017). NMFS recently reviewed this evidence in their biological opinions on fisheries conducted under the Pacific Fishery Management Council Salmon Fishery Management Plan for Southern Resident killer whales (National Marine Fisheries Service 2020, 2021). Several studies in the past have identified correlations or connections between Chinook salmon abundance indices and Southern Resident killer whale health, survival, social cohesion, growth rate, and fecundity (Ward et al. 2009; Ayres et al. 2012; Ford et al. 2010; Fearnbach et al. 2011; Ward et al. 2013; Wasser et al. 2017; Fearnbach et al. 2020).

Researchers have also applied temporal measures of fecal hormone metabolites to test competing hypotheses of nutritional limitation and vessel disturbance as well as potential interactions on indices of long-term nutritional state (triiodothyronine) as well as more short-term physiological stress (glucocorticoids, or GCs)(Ayres et al. 2012; Wasser et al. 2017). Ayres et al. (2012) showed that GCs correlate closely with Fraser River Chinook salmon on short time scales with GCs decreasing with increasing Fraser River salmon abundance and that vessel disturbance may interact with this correlation but Fraser River Chinook salmon explained the most variance in the data. They also showed that the Southern Residents tend to come into the Salish Sea in the spring and early summer with higher thyroid hormone that decreases over time into the late fall months. This pattern was suggestive that the Southern Residents are less food limited at the start of the summer coincident with the time following the coastal early spring Columbia River Chinook salmon run which is consistent with telemetry data indicating K and L pod foraging off the Columbia River (Hanson et al. 2013) that time of year.

Wasser et al. (2017) built on the work of Ayres et al. (2012) and used reproductive hormone metabolites of progesterone and testosterone to test the hypothesis that low nutritional state results in reproductive failure at various levels. Models from this study suggest that nutritional stress is associated with reproductive failure.

In addition to the physiological effects of reduced prey abundance that have been observed in Southern Residents, there is also evidence of a negative impact on social cohesion when salmon abundance is low (Parsons et al. 2009; Foster et al. 2012). Social cohesion likely plays an important role in Southern Resident survival, growth, and reproduction. When prey abundance is low, whales must spread out to find food and dedicate more of their time to foraging rather than on social interactions such as reproduction and information transmission (Foster et al. 2012). Researchers have observed a correlation between reduced reproduction in Southern Residents and low salmon abundance (Ford et al. 2010), although this correlation is weaker in recent years than it was in the past (see paragraph above). So, it is unclear to what extent the interruption of social cohesion as a result of reduced salmon abundance may impact the population or limit recovery.

In recent years, the relationship between Chinook salmon abundance and Southern Residents demographic rates have weakened (e.g., Southern Resident status continues to decline with varying levels of Chinook salmon abundance) and uncertainty remains due to several challenges in quantitatively characterizing the relationship between Southern Residents abundance and Chinook salmon abundance (National Marine Fisheries Service 2020, 2021; Pacific Fishery Management Council 2020). Also, documented relationships to date between Southern Residents and Chinook salmon are biased toward the summer and early fall months, and Chinook salmon stocks in the Pacific northwest at that time, because Southern Residents are more accessible to boat-based researchers at that time of year but spatial-temporal data suggest that K and L pods make excursions to the coast of Oregon and California in the winter and early spring. While data are still limited at this time, there has been enough research on the whales in the outer coast that supported extending critical habitat down to Monterey Bay.

The CVP and SWP operations may affect Chinook salmon available to Southern Residents, particularly K and L pods when they occur in the coastal waters off Oregon and California in the winter and early spring. As K and L pods travel south to the waters off Oregon and California, Central Valley Chinook salmon and Trinity River Chinook salmon become more prevalent making up a larger proportion of the Chinook salmon available as prey.

Prey availability for the Southern Residents is affected by ocean conditions, habitat limitations, hydrology alterations, hatchery production, fishery harvest, contaminants, and competition with other predators. In the Pacific Northwest, ESUs of salmon and steelhead have been listed as threatened or endangered in Washington, Oregon, Idaho, and California. Commercial, sport, and tribal fisheries harvest salmon in the ocean. Between 2010 and 2021, harvest of Chinook salmon within the range of the Southern Residents, including Haida Gwaii, Canada to Monterey Bay, USA, has averaged 611,297 fish annually (Pacific Fishery Management Council 2023b; Pacific Salmon Commission 2022) and regulations have been modified due to this action's impact on Southern Residents prey availability (National Marine Fisheries Service 2021d).

O.2 Methods and Tools

This section describes the technical background for the evaluation of environmental consequences associated with the action alternatives and the No Action Alternative.

The impact assessment considers changes in flows, temperature, and other habitat conditions related to changes in CVP and SWP operations under the action alternatives as compared to the No Action Alternative. This section details methods and tools used to evaluate those effects. All four phases are considered in the assessment of Alternative 2 to bracket the range of potential impacts.

The impact assessment considers changes in flows, temperature, and other habitat conditions related to changes in CVP and SWP operations under the action alternatives as compared to the No Action Alternative. This section details methods and tools used to evaluate those effects.

The following model simulations were utilized to analyze and compare the No Action Alternative and action alternatives:

- CalSim 3
- HEC-5Q
- Reclamation Temperature Model
- DSM2
- USRDOM (Upper Sacramento River Daily Operations Model)

Each of these model simulations is summarized below and are more fully described in Appendix F, *Modeling*.

A full suite of biological models was also utilized to analyze and compare the No Action Alternative and action alternatives. Most of the models require CalSim 3 flows and/or HEC-5Q temperature outputs as inputs, along with other inputs such as USRDOM daily flows or DSM2). Details on models, methods, and results are included below. Each of these models (overview, methods) and associated results are summarized and fully described in independent attachment documents.

O.2.1 CalSim 3

The Reclamation/DWR CalSim 3 planning model was used to simulate the coordinated operation of the CVP and SWP over a range of hydrologic conditions. CalSim 3 is a generalized reservoir-river basin simulation model that allows for specification and achievement of user-specified allocation targets, or goals (Draper et al. 2004). CalSim 3, an updated version of CalSim II, represents the best available planning model for CVP and SWP system operations and has been used in previous system-wide evaluations of CVP and SWP operations (Bureau of Reclamation 2015).

O.2.2 HEC-5Q

Over the past 15 years, various temperature models were developed to simulate temperature conditions on the rivers affected by CVP and SWP operations (SRWQM, San Joaquin River HEC-5Q model) (Bureau of Reclamation 2008). Recently, these models were compiled and updated into a single modeling package called in here as the HEC-5Q model. Further updates were performed under the EIS modeling that included improved meteorological data and subsequent validation of the Sacramento River and American River models, implementation of the Folsom temperature control devices and low-level outlet, implementation of the Trinity auxiliary outlet, improved temperature targeting for Shasta and Folsom Dams, as well as improved documentation and streamlining of the models as well as improved integration with the CalSim 3 model (Bureau of Reclamation 2015).

O.2.3 Reclamation Temperature Model

The Reclamation Temperature Model includes reservoir and stream temperature models, which simulate monthly reservoir and stream temperatures used for evaluating the effects of CVP/SWP project operations on mean monthly water temperatures in the basin (Bureau of Reclamation 2008). The model simulates temperatures in seven major reservoirs (Trinity, Whiskeytown, Shasta, Oroville, Folsom, New Melones, and Tulloch), four downstream regulating reservoirs (Lewiston, Keswick, Goodwin, and Natoma), and five main river systems (Trinity, Sacramento, Feather, American, and Stanislaus). The river component of the Reclamation Temperature Model calculates temperature changes in the regulating reservoirs, below the main reservoirs. With regulating reservoir release temperature as the initial river temperature, the river model computes temperatures at several locations along the rivers. The calculation points for river temperatures generally coincide with tributary inflow locations. The model is one-dimensional in the longitudinal direction and assumes fully mixed river cross sections. The effect of tributary inflow on river temperature is computed by mass balance calculation. The river temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data (Bureau of Reclamation 2015).

O.2.4 DSM2

DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento–San Joaquin Delta (Anderson 2002). DSM2 represents the best available planning model for Delta tidal hydraulic and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental environmental impacts caused by future facilities and operations (Reclamation 2015).

O.2.5 Interactive Object-Oriented Simulation

The Interactive Object-Oriented Simulation (IOS) Model is composed of six model stages defined by a specific spatiotemporal context and are arranged sequentially to account for the entire life cycle of winter-run Chinook salmon, from eggs to returning spawners. In sequential order, the IOS Model stages are: spawning, early development, fry rearing, river migration, Delta passage, and ocean survival.

O.2.6 Oncorhynchus Bayesian Analysis

The winter-run Chinook salmon Oncorhynchus Bayesian Analysis (OBAN) model has been developed from the conceptual life cycle model of winter-run Chinook salmon and coded into Windows-based software with graphic output capability. The Bayesian estimation of model coefficients was coded into WinBUGS. The software finds a statistical "best fit" to empirical trends by matching model predictions to empirically observed juvenile and adult abundances. The model is capable of fitting abundance data sources and estimating number of coefficient values to find the best statistical prediction.

O.2.7 Central Valley Project Implementation Act Science Integration Team Lifecycle Models

Life cycle models can be used to compare natural production and demographic rates of winter-run and spring-run Chinook salmon. The CVPIA SIT DSM models were developed by the CVPIA Science Integration Team (SIT) as part of a Structured Decision Making process, and the models, as implemented in R, are open source and publicly available. See: https://cvpia.scienceintegrationteam.com/cvpia-sit/resources/dsm-r-packages. Analyses using a version of the DSMs have been published (Peterson and Duarte 2020). These models can incorporate CalSim flow and HEC-5Q temperature data from the Sacramento River and tributaries. The original purpose of these DSMs was to compare outcomes of different restoration scenarios, but they would also be appropriate for comparisons of different flow and temperature scenarios. These models can inform multiple performance metrics for Chinook salmon, including Delta routing and survival probabilities.

O.2.8 Delta Smelt Life Cycle Model

Polansky et al. (2020) developed a stage-structured state-space life cycle model for Delta Smelt. State-space models are useful as ecological modeling tool because they allow separate descriptions of state and observation processes and because they permit integration of disparate data sets. This Delta Smelt life cycle model (LCM) was later expanded from four to seven different life stages and to include a component that describes the entrainment process into the Delta export facilities (Smith et al. 2021). This model produces expected values for larval recruitment and survival at the subsequent life stages. The best model in Smith et al. (2021) also used OMR values at a monthly scale and therefore, CalSim output for the alternatives can be directly incorporated into the analysis. As such, Reclamation can use this model to calculate expected annual population growth rate (λ). The metric of interest will be geometric mean of λ for a specified time period (e.g., 1995-2015), which will be compared across alternatives.

O.2.9 Survival, Travel time, and Routing Simulation

The Survival, Travel time, and Routing Simulation Model (STARS) is an individual-based simulation that predicts fish parameters (survival, travel time, entrainment) of juvenile salmonids migrating through the Delta. The fish parameters are related to movement of individual acoustically tagged late-fall and winter-run Chinook salmon connected to daily data (DCC gate status and Sacramento River flow at Freeport). The implementation of the simulation model currently available for use is calibrated to acoustically tagged late-fall fish released from 2007 to 2011. Data inputs to the model can be obtained by assigning monthly CalSim output to daily values within each month. Results are for individuals in cohorts, or fish who enter the model's

"system" daily at Freeport. The use of the STARS model can inform the migrating behavior of juvenile salmonids (i.e., route selection) and total survival in the Delta. It is constructed to understand the space outside the interior Delta, but interpolation could be used to identify possible behavior of fish once they take a specific route away from the Sacramento River (i.e., Delta Cross Channel or Georgiana Slough). STARS provides overall survival and travel time, route-specific survival and travel time, and proportion of fish on a daily timestep that would use individual migration pathways or routes. An application of the STAR models run in real time is available here: https://oceanview.pfeg.noaa.gov/shiny/FED/CalFishTrack/. The code and supporting document are available from USGS (Russ Perry, USGS, Personal Communication). The model structure and assumptions are documented in peer-reviewed literature (Perry et al. 2018). Model development is not currently open and participatory.

The STARS model can be applied to assess the performance metric of routing probability for winter-run Chinook salmon and possibly also spring-run Chinook salmon. The STARS model was applied to the 2019 NMFS Biological Opinion.

O.2.10 Delta Passage Model

The Delta Passage Model (DPM) is based on migratory pathways and reach-specific mortality as Chinook salmon smolts travel through a simplified network of reaches and junctions. The biological functionality of the DPM is based on releases of acoustically tagged Chinook salmon performed between 2007 and 2017. The current model is based on acoustically tagged winter-run, spring-run, fall-run and late fall–run individuals (≥ 80 mm) released in the upper reaches of the Sacramento River and within the Delta. These releases are primarily comprised of hatchery fish. However, wild spring and fall run are included in the dataset. These releases cover a wide range of environmental conditions, including extreme drought in 2014 and 2015 and high flow years. Uncertainty is explicitly modeled in the DPM by incorporating environmental stochasticity and estimation error whenever available. The major model functions in the DPM are as follows: 1) delta entry timing, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon, 2) fish behavior at junctions, which models fish movement as they approach river junctions, 3) migration speed, which models reach-specific smolt migration speed and travel time, 4) route-specific survival, which models route-specific survival response to non-flow factors, 5) flow-dependent survival, which models reach-specific survival response to flow, and 6) export-dependent survival, which models survival response to water export levels in the interior Delta reach. The DPM model can be used to assess the survival of smolts from Delta entry to Chipps Island performance metrics for winter-run or spring-run Chinook salmon. Model documentation for previous iterations of the model is available in an accompanying report (Cavallo et al. 2011). The model was applied in the NMFS 2019 Biological Opinion. Model development and the current application is not fully open and participatory.

The DPM operates on a daily timestep using simulated daily average flows and south Delta exports as model inputs. Water movement through the Delta as input to the DPM is derived from daily (tidally averaged) flow output produced by the hydrology module of the Delta Simulation Model II (DSM2- HYDRO; http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/) or from CalSim 3.

O.2.11 Particle Tracking Model

The particle tracking model (PTM) component of DSM2 computes the location of an individual particle at any time step within a channel based on velocity, flow and water level information provided by HYDRO. The longitudinal movement is based on transverse and vertical velocity profiles computed from mean channel velocity provided by HYDRO. PTM has multiple applications ranging from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae. PTM is publicly available from DWR at CADWRDeltaModeling/dsm2: Delta Simulation Model 2 (github.com).

O.2.12 Ecological Particle Tracking Model

The ecological particle tracking model (ECO-PTM) was developed by DWR, in collaboration with USGS, and applies to juvenile Chinook salmon migration. Currently built upon data from acoustically tagged late fall–run Chinook salmon (2006 – 2014), the ECO-PTM estimates routing through Georgiana Slough, Delta Cross Channel route, the Sutter / Steamboat slough complex, or remaining in the Sacramento River. Development of the model is still ongoing and currently focused on the south Delta. This model was recently used in evaluating the biological effects of the spring 2022 Temporary Urgency Change Petition (TUCP), and code is available from DWR at https://data.cnra.ca.gov/dataset/ecological-particle-tracking-model-eco-ptm.

ECO-PTM can be used to evaluate survival, travel time, and routing probabilities, and thus apply to the seasonal loss and zone of entrainment performance metrics for winter-run and spring-run Chinook salmon. This model can incorporate CalSim or DSM2 data as model input.

O.2.13 Zone of Influence

The Sacramento–San Joaquin River Delta (Delta) provides habitat for migrating anadromous fish while also serving as critical infrastructure for California water supply. In the winter and spring months, Old and Middle River (OMR) flows are managed to protect emigrating Delta smelt, longfin smelt, juvenile winter-run Chinook salmon, yearling spring-run Chinook salmon, and Central Valley steelhead from entrainment into the export facilities in the south Delta. During these months, changes to velocity distributions in channels, due to south Delta exports, may affect the fate of fish. This model evaluates the spatial extent of hydrologic alteration considering changes to velocity (hereinafter described as “Delta export zone of influence”) and changes to the probability distributions of hourly average velocity as a result of pumping under varying OMR flow conditions. An analysis using DSM2-Hydro was conducted to analyze the spatial extent of influence of exports under CVP and SWP diversions. The DSM2-Hydro velocity results were used to generate Delta export zone of influence contour maps in the Delta.

O.2.14 Negative Binomial Model

To evaluate potential changes to the number of LAD winter-run and spring-run Chinook salmon salvaged at the CVP and SWP pumping facilities based on the alternatives, Reclamation analyzed historical salvage data via negative binomial regression. Negative binomial regression requires estimation of a dispersion parameter rather than assuming the variance is equal to the mean. In doing so, negative binomial regression can account for overdispersion, which is common in ecological data (e.g., the salvage dataset), as well as reduce the likelihood of biased coefficient estimation.

O.2.15 Salvage Density Model

For each species at each month at each facility, density (fish / TAF) was calculated as total monthly loss or expanded salvage for the facility divided by total monthly volume of exported water. Assuming a linear relationship between entrainment and flow may be an oversimplification so the method "functions as a description of changes in export flows weighted by seasonal changes in salvage density of covered species". Mean monthly entrainment indices for each month of each water year type is calculated as salvage or loss density multiplied by CALSIM modeled export value for the same month for all years with the same water year type.

This method can be used to compare the salvage index calculated from one export scenario to another and relies on historical salvage data to estimate changes in entrainment at the SWP/CVP export facilities providing a description of "changes in export flows weighted by seasonal changes in salvage density of covered species".

O.2.16 Winter-Run Chinook Salmon Coded-Wire Tag Loss

The Winter-Run CWT Proportional Salvage Model was developed to estimate the fraction of juvenile winter-run Chinook salmon in the Delta predicted to be salvaged based on hydrologic conditions and fish size. The model is based on the models of Zeug and Cavallo (2014) who analyzed > 1000 release groups representing, more than 28 million coded wire tagged juvenile fish including winter, late fall and fall run Chinook salmon. These data are extremely useful because they represent large release groups of tagged smolts where the number of fish representing each release group salvaged at the export facilities has been estimated. Analysis of "raw" salvage (observed salvage without scaling by starting population size) is problematic because the actual stock or basin of origin is often unknown (e.g. poor performance of length-at-date curves). Furthermore, with "raw" salvage, the number of smolts produced and potentially exposed to entrainment and salvage is unknown. The CWT salvage data analyzed by Zeug and Cavallo (2014) overcomes these deficiencies and provides the most appropriate basis for defining stock-specific categories of entrainment risk.

A model specific to winter-run Chinook salmon was constructed by Zeug and Cavallo (2015) to examine the level of evidence for additional hydrologic metrics. This model combined salvage at both the CVP and SWP rather than modeling them separately as was done in Zeug and Cavallo (2014). The model selection exercise included five potential hydrologic predictor variables including Old-Middle River flow (OMR), inflow-export ratio (I-E), total exports, San Joaquin River flow, Sacramento River flow and one biological variable (mean fork length at release).

O.2.17 Longfin Smelt Salvage | OMR

The longfin smelt (LFS) salvage OMR relationship is a model of salvage at South Delta facilities as a function of flow based on historical salvage data. The results are a quantitative analysis of loss differences between operating scenarios (including the Proposed Action). The method uses data from 1993-2005, reflective of historically high periods of juvenile salvage at the CVP and SWP collection facilities and OMR flows. This period represents conditions prior to the 2009 Biological Opinion and conditions under the 2019 Biological Opinion.

O.2.18 Flow into Junctions

Many routes can potentially be used by fish migrating through the Delta and survival through these routes can be significantly different (Newman 2008; Perry et al. 2010). Thus, routing of fish at junctions and how routing could be affected by project operations has the potential to influence through-Delta survival. In general, routes that keep fish in the mainstem Sacramento and San Joaquin rivers are superior to routes leading into the interior Delta (Dauble et al. 2010; Perry et al. 2010), although some recent findings for the San Joaquin River have not supported this generality (Buchanan et al. 2013). Perry (2010) found that the routing of fish into the interior delta through the combined junction of Georgiana Slough and the Delta Cross Channel was a function of the total flow entering the interior delta through both of those junctions. This is the function represented in Figure 6.7 within Perry (2010). This function indicated that the slope of the relationship was less than 1. Cavallo et al. (2015) performed a meta-analysis of routing at 6 Delta junctions and found that the proportion of flow entering a junction explained 70% of the variation in routing. Similar to the Perry (2010) study, the slope of this relationship was less than 1 suggesting fish move into junctions at a rate less than the proportion of flow.

Both of the studies above present strong evidence that routing at junctions is a function of the proportion of flow into that junction. Thus, estimating the proportion flow entering a Delta junction can be strongly predictive of the proportion of migrating salmonids that may move from the main channel into a distributary. In this effort the daily proportion of flow entering a distributary junction is rolled up into monthly values. Increases in the proportion of flow into a distributary channel under alternative scenarios would allow us to evaluate the likelihood of fish migration into junctions.

O.2.19 Zooplankton Delta Outflow

This line of evidence followed the general framework of similar, prior analyses (Kimmerer 2002; Hennessy and Burris 2017; Greenwood 2018; California Department of Water Resources and Bureau of Reclamation 2023) to examine the relationship between Delta outflow and Delta smelt and longfin smelt zooplankton prey density (catch per cubic meter) in the low salinity zone (i.e., 0.5–6 parts per thousand salinity). The analyses related prey density to Delta outflow during winter (December - February), spring (March–May), summer (June–August), and fall (September–November) for the period from 2000 to 2021. This period generally represents the onset of the Pelagic Organism Decline ecological regime (Thomson et al. 2010). Zooplankton examined in the analyses were based on taxa (species or species groupings, split by life stage where appropriate) included in recent modeling and diet studies of both Delta smelt and longfin smelt (Slater and Baxter 2014; Smith 2021; Barros et al. 2022; Smith and Nobriga 2023). Results demonstrate the relationship between abundance of smelt prey in the Delta and outflow, controlled by CVP and SWP seasonal operations.

O.2.20 XT

In-river migration can be analyzed using the passage component ("Migration Model") of the SacPAS Fish Model. The model is a reconfiguration of the National Marine Fisheries Service Comprehensive Passage (NMFS COMPASS) smolt passage model, developed for Columbia River salmon and steelhead (Zabel et al. 2008). Water velocity in a reach is determined with a power curve relationship between flow and velocity in a free-flowing reach. Fish passage time through a reach is a function of water velocity. Fish survival through a reach is a function of

distance travelled and travel time to complete that distance. Both water and fish properties (i.e., velocity, travel time) are computed on sub-daily time steps. The survival sub-model is calibrated from acoustically tagged fall-run Chinook salmon (Steel et al. 2020). The XT model (Anderson et al. 2005), which the SacPAS Fish Model utilizes, assumes fish are similar between cohorts but the environment they experience is different. Flow varies spatially and temporally and there is a trade-off between the distance (X) a fish travels and the time spent (T) for a fish in a reach when calculating survival.

O.2.21 Flow Threshold Salmon Survival

A flow threshold model was used to assess potential effects of changes in flow in the Upper Sacramento River on juvenile Chinook salmon as a result of flow-survival relationships. The flow thresholds from Michel et al. (2021) were applied to Sacramento River at Wilkins Slough. The model estimates the annual mean probability of juvenile Chinook salmon survival in the Sacramento River between the confluence of Deer Creek and Feather River between March 15 and June 15. Annual mean survival was calculated from daily survival estimates.

O.2.22 Delta Outflow | Sturgeon Year Class Index

This analysis assesses potential effects of the proposed project and alternatives on white or green sturgeon year-class strength (YCI) using a correlative relationship between Delta outflow and white sturgeon YCI based on Fish (2010). The analysis uses historical Delta outflow and white sturgeon YCI data to establish the relationships. Modeled Delta outflow values from CalSim 3 are then used as input to these relationships to estimate white sturgeon YCI. White sturgeon YCI is used as a surrogate to estimate green sturgeon YCI.

O.2.23 Delta Outflow | Bay-Delta Species Abundance

This analysis assesses potential effects of the proposed project and alternatives on four Bay-Delta aquatic species with known relationships from Kimmerer et al. (2009) between their indices of annual abundance and Delta outflow – striped bass, American Shad, starry flounder, and California bay shrimp. The analysis relies on historical Delta outflow values and species abundance indices from regional monitoring programs. Modeled Delta outflow values from CalSim 3 are then used as input to these relationships to compare scenarios for each species.

O.2.24 Longfin Smelt Spring Outflow

The potential effect of operations on longfin smelt abundance was investigated through development of a statistical modeling approach relating the Longfin Smelt Fall Midwater Trawl (FMWT) abundance index to: (1) Delta outflow; (2) the FMWT abundance index two years earlier (as a representation of parental stock size), and; (3) ecological regime (i.e., 1967–1987, pre-*Potamocorbula amurensis* invasion; 1988–2002, post-*P. amurensis* invasion; and 2003–2022, Pelagic Organism Decline). The inclusion of the regime factor represents major ecological changepoints in the Bay-Delta (e.g., Nobriga and Rosenfield 2016; Sommer et al. 2007). Total Delta outflow (thousand acre-feet) was summed and examined as an explanatory covariate for two overlapping time periods: December through May, and March through May. Similar time periods have also been investigated in previous studies by Mount et al. (2013) and Nobriga and Rosenfield (2016). Bayesian methods were used to take into account model uncertainty (e.g., uncertainty in the time period over which Delta Outflow is considered to be affecting Longfin

Smelt abundance). Thereby integrating an important component of scientific uncertainty into the resulting model predictions for decision making.

O.2.25 Revised Maunder and Deriso

The Delta Smelt life cycle model published by Maunder and Deriso (2011) was updated in 2021 following the approach of Polansky et al. (2021) as far as practical, by modifying and generalizing the originally published model. This update to the publication version (henceforth referred to as the Maunder and Deriso model in R, or MDR) models a single cohort life strategy species that dies after it reproduces (i.e. the final transition is from adults to recruits and very few adults survive to the next time period e.g. an annual species). It is modeled in a Frequentist state-space framework allowing for both process variation and observation error. Transition between stages (i.e. survival and the stock-recruitment relationship) can be a function of density and covariates, in addition to unexplained temporal variation (process error). Covariates can also be used to influence the density dependent relationship or the survey catchability (bias). The model can be fitted to any number of surveys representing any of the stages. There is also flexibility in the timing of density dependence, surveys, process error and covariates. The covariates can be estimated as random variables to represent uncertainty in the measurement of the covariates, dealing with missing covariates, or allowing for uncertainty in projections, but this is not illustrated here.

Relative to the 2011 publication, the MDR includes an additional stage (sub-adults), with stages adjusted appropriately, fit to two additional indices of abundance for adults (spring midwater trawl prior to 2001 and spring Kodiak trawl for 2001 and later). Additionally, catchability (survey bias) is now estimated for the spring midwater trawl, and the likelihood function was changed to a log normal. The time period was also extended and now includes cohorts between 1995 and 2015. Potential covariates of survival and recruitment were borrowed from Smith et al., (2021). The surveys were fitted at the start of the stage before any other processes occurred. Covariates and process variation were added after density dependence when it was included.

O.2.26 Winter-Run Chinook Salmon Juvenile Production Index

The Juvenile Production Index (JPI) is a standardized estimate of juvenile winter-run Chinook salmon passage at Red Bluff Diversion Dam. Juvenile Chinook salmon migrate past Red Bluff at various life stages and passage may occur days to months following emergence. The USFWS uses an assumed survival rate between the fry life stage and all-post fry life stages to standardize the estimate into “fry equivalents”. The analysis of the JPI model coupled with multi-model averaging led to the identification of two environmental drivers that most affect juvenile winter-run Chinook salmon production. The JPI model incorporates interannual variation of flow as an environmental factor in conjunction with temperature and the estimated number of female winter-run Chinook salmon spawners. This is important because previous modeling efforts have focused on the effect of temperature on egg-to-fry survival, a calculation that uses the response used here (JPI) but with additional estimates and assumptions (Martin et al. 2017, Anderson et al. 2022). Neither of the previous studies have examined the effect of flow and have instead assumed non-temperature effects were equal among all years.

O.2.27 Sacramento River Weighted Usable Area

Weighted usable area (WUA) analysis is a method for estimating the availability of suitable habitat in rivers, streams, and floodplains under different flow conditions (Bovee et al. 1998). It has been used primarily for estimating spawning and rearing habitat of fish species. WUA is computed as the surface area of physical habitat available for spawning or rearing, weighted by its suitability. Habitat suitability is determined from field studies of the distributions of redds or rearing juveniles with respect to flow velocities, depths, and substrate or cover in the river or floodplain (Bovee et al. 1998). These data are used in hydraulic and habitat model simulations (e.g., PHABSIM or RIVER2D) that estimate the availability of suitable habitat in a portion of the river at a given flow. WUA curves showing suitable habitat availability versus flow are generated from the simulations. These curves facilitate evaluating how different flow regimes affect spawning and rearing habitat of important fish species.

O.2.28 Sacramento River Dewatering Analysis

Redd dewatering for salmon and steelhead occurs when the water level drops below the depth of an existing redd or drops low enough to cause lethal conditions for incubating eggs or alevins within a redd. Redd dewatering in a spawning habitat can occur at any time between the start of spawning to the final emergence of alevins from the redd. Fluctuations in flow during this period increase the probability of redd dewatering because higher flows could lead to redd placement in areas that subsequently may be dewatered when flows drop.

The redd dewatering analyses for the Sacramento River are based on the maximum reduction in flow from the initial flow, or *spawning flow*, that occurs over the duration of an egg cohort. The duration of a cohort in a redd includes egg incubation and alevin development to emergence from the gravel. Based on technical assistance from the National Marine Fisheries Service (NMFS), cohort duration was estimated as three months for the four Sacramento River Chinook salmon races (fall-run, spring-run, winter-run, and late fall–run) and steelhead. The minimum flow of the egg cohort period is referred to herein as the *dewatering flow*. If flows during the three months subsequent to spawning are all greater than the spawning flow, no dewatering is assumed to occur.

O.2.29 Sacramento River Juvenile Stranding Analysis

Juvenile stranding of salmon and steelhead occurs when the water level (stage) falls and water recedes from habitats occupied by juveniles in such a way as to isolate the juveniles from river mainstem. This typically occurs on gravel bars or side channel habitats and can be a natural process and part of a river's disturbance regime (Larrieu et al. 2020). Juveniles in pools are especially at risk, becoming stranded as the pool loses its fluvial connection to the main channel. Stranded juveniles are vulnerable to predation, reduced water quality, and exposure to air (Nagrodski et al. 2012; Revnak et al. 2017). Sublethal effects can range from temporary metabolic stress to chronic hypoxia (Larrieu et al. 2020). This analysis on juvenile stranding in the Sacramento River is based on results of field studies and analyses reported in U.S. Fish and Wildlife Service (USFWS) 2006.

O.2.30 Salmort Egg Mortality models

The Salmort egg mortality model was used to estimate the change in survival in fall run and late fall-run Chinook salmon in the Sacramento River from changes in early life stage survival attributable to water temperature. This model uses the water temperature model outputs along with Chinook salmon spawning distribution and abundance to estimate water temperature effects onto pre-spawned eggs, incubating eggs, and alevins.

O.2.31 Winter-run Temperature Dependent Mortality

The Martin et al. (2017) or Anderson et al. (2022) models can be used to predict egg-to-fry survival for winter-run Chinook salmon as a function of temperature-dependent egg mortality, background mortality, and density-dependent mortality. Both models specify egg mortality as a function of temperature (i.e., temperature-dependent mortality, or TDM), applied over either the entire embryonic developmental period (i.e., stage-independent or Martin model) or only part of it (i.e., stage-dependent or Anderson model), based on an estimated minimum temperature at which no temperature-dependent mortality occurs and a slope term that describes how much increasing temperatures above the minimum affect egg mortality. Density-dependent mortality is specified following the Beverton-Holt function with a corresponding carrying capacity density term. Model parameters were estimated using known redd locations, estimated temperatures, and annual estimates of egg-to-fry survival from either 1996-2015 (Martin et al. 2017) or 2002-2020 (e.g., Poytress 2016; Anderson et al. 2022). Datasets necessary to run the models include the abundance of redds over space and time and corresponding daily temperatures for each redd location; historical aerial redd or carcass survey data and HEC-5Q daily temperature estimates can and have been used as model inputs. These models are available to run as part of the SacPAS Fish Model implementation at: https://www.cbr.washington.edu/sacramento/fishmodel/. The Martin and Anderson models was be used to evaluate the stand-alone temperature-dependent mortality, but Reclamation notes they can evaluate overall egg to fry survival performance metrics for winter-run Chinook salmon. Model development was not open and participatory. Versions of both models were applied in the 2019 Biological Assessment and Biological Opinion.

The models are sensitive to the temperature target, locations, and timing. The Proposed Action (i.e., Alternative 2) developed bins with different water temperature management biological goals and objectives (i.e., “Bin Criteria”). The Proposed Action additionally included shaping water temperature management to optimize for low TDM. The models used and updated the 2020 Record of Decision into a strategy that may better represent the outcome of temperature shaping by the real-time groups (i.e., “2021 Updated Tier Strategy”). Reclamation staff present all results for Alternative 2 with “Bin Criteria” temperature target, locations, and timing, in addition to select results in which the “2021 Updated Tier Strategy” is applied instead to the No Action Alternative (NAA) and components of the Proposed Action. Reclamation staff explicitly identify all instances in which results reflect the “2021 Updated Tier Strategy”.

O.2.32 Sacramento River Temperature Analysis

Temperature analysis enumerates the frequency at which mean monthly HEC-5Q simulated water temperatures exceed water temperature index values or occur outside index ranges for multiple fish species in the Sacramento River upstream of the Delta. Index values and ranges were obtained from the scientific literature and agency reports for each species and life stage at multiple locations within the river. Frequencies were calculated for the baseline and each alternative at one or more locations of life stage presence in the river by month of presence and water year type and the incremental change between the baseline and each alternative was then calculated.

O.2.33 Clear Creek Temperature Analysis

Temperature analysis in Clear Creek follows the same methodology as in the Sacramento River.

O.2.34 Clear Creek Weighted Usable Area (spawning and rearing)

The Clear Creek WUA Analysis follows the same methodology as in the Sacramento River.

O.2.35 American River Weighted Usable Area

The American River WUA Analysis follows the same methodology as in the Sacramento River.

O.2.36 American River Temperature Analysis

The American River temperature analysis follows the same methodology as in the Sacramento River.

O.2.37 American River Redd Dewatering Analysis

The American River redd dewatering analysis follows the same methodology as in the Sacramento River.

O.2.38 Stanislaus River Weighted Usable Area

Estimation of spawning and rearing habitat availability for salmonids in the Stanislaus River was based on procedures from two different studies. Weighted usable area (WUA) analysis was the principal methodology used to quantify spawning habitat availability for fall-run Chinook salmon and steelhead in the river. WUA was also used to quantify rearing habitat of fry and juvenile fall-run and steelhead in the river, but an additional procedure, based on spatially explicit hydrodynamic modeling and geographic information system (GIS) tools (hereinafter referred to as “ASH analysis” for “Area of Suitable Habitat”) was employed to estimate rearing habitat availability. The three methodologies, consisting of one for evaluating spawning habitat and two for analyzing rearing habitat, are described and discussed below.

O.2.39 Stanislaus River Temperature Analysis

The Stanislaus River temperature analysis follows the same methodology as in the Sacramento River.

O.2.40 Central Valley Project Improvement Act Science Integration Team Decision Support Model Habitat Models

Estimates of suitable habitat for Chinook salmon life stages, including spawning adults and rearing juveniles, that vary as a function of flow are estimated in this analysis using two methods: (1) WUA based on hydraulic modeling and habitat suitability curves and (2) the combination of hydraulic modeling and minimum habitat quality thresholds (e.g., HEC-RAS). For both methods, reference tables were created that link flow values to corresponding estimates of habitat. These relationships are often non-linear, such that increasing flow can either increase or decrease estimates of available habitat. Reference tables and functions for linking flow to habitat estimates were obtained from the DSMhabitat package developed by FlowWest (CVPIA-OSC/DSMhabitat: Habitat estimates for the life cycle models developed by CVPIA's Science Integration Team (github.com)), which is applied in support of CVPIA SIT Decision Support Models (DSMs) for Central Valley salmonids. Reclamation staff most recently installed the DSMhabitat package on 9/18/23. For rearing in-stream habitat, habitat estimates were obtained for the "juvenile" life stage category from the DSMhabitat functions (i.e., separate relationships were developed for "fry" and "juvenile"). Modeling details for flow-habitat relationships for selected watersheds (i.e., Upper Sacramento River, Clear Creek, American River, Stanislaus River, Yolo Bypass, Sutter Bypass) are provided in supporting documentation at the following site: Habitat Data — habitat_data • DSMhabitat (cvpia-osc.github.io). The Science Integration Team Decision Support Model was co-produced by technical experts with the purpose of evaluating potential actions within CVPIA's authority, primarily habitat restoration. Note assumptions made for the purpose of prioritizing habitat restoration actions may not be valid when applied to project operations.

O.3 No Action Alternative

Under the No Action Alternative, Reclamation would operate the CVP consistent with the 2020 Record of Decision (2020 ROD), implementing the Proposed Action consulted upon for the 2019 Biological Opinions and the reasonable and prudent measures in the incidental take statements. DWR would operate the SWP consistent with the 2020 ROD and its 2020 Incidental Take Permit (2020 ITP). Pursuant to 43 Code of Federal Regulations Section 46.30, the 2020 ROD for the CVP and SWP and the 2020 ITP for the SWP represent current management or intensity for the purposes of the No Action Alternative. The No Action Alternative is fully described in EIS Chapter 3, *Alternatives*.

Modeled results under the No Action Alternative are discussed in the Alternatives sections, as each Alternative relates to the No Action Alternative. These results include CalSim 3 flows, Hec-5Q temperatures, and quantitative predictions from secondary biological models (e.g., Temperature Dependent Mortality (TDM, Anderson and Martin), survival and routing from the Survival, Travel Time, and Routing Simulation Model (STARS), spawner abundance from the Science Integration Team Lifecycle Model).

O.3.1 Sacramento River Winter-Run Chinook Salmon ESU

O.3.1.1 Sacramento River

No Action Alternative Components and Winter-run Chinook Salmon

The No Action Alternative consists of components common to all other Alternatives ("common components") and components unique to the No Action Alternative. Discussed here are all components that occur on the Sacramento River and how operations of those components under the No Action Alternative may impact the life stages of winter-run Chinook salmon present in the system.

- **Fall Operations and Rice Decomposition Smoothing:** In the fall, Reclamation's objective is to reduce Keswick Dam releases and rebuild storage in Shasta Reservoir. Reclamation balances fall operations based on highly variable conditions, including water temperature control (dependent on winter-run Chinook salmon emergence timing), maintenance of winter-run Chinook salmon redds (dependent on spawning depths), instream diversion demands on the mainstem of the Sacramento River upstream and downstream of Wilkins Slough (dependent on seasonal planting and wildlife refuges), fall-run Chinook salmon redd dewatering minimization (dependent on late-summer flows and fall spawning timing), and release stabilization through the fall-run Chinook salmon egg and alevin incubation.

  Reclamation will release flows based on Sacramento Valley Water Service Contractors demand and SRS Contractors coordinated rice decomposition smoothing diversion schedule. SRS Contractors and CVP Water Service Contractors will synchronize their diversions to lower peak rice decomposition demand. The delivery schedule considers dewatering risk for winter-run Chinook salmon redd locations.

Release reductions from Shasta Reservoir early in the fall and other common components, like rice decomposition smoothing, would continue under the No Action Alternative and may negatively affect the population including dewatering risks for winter-run Chinook salmon redd locations.

- **Ramping Rates:** Ramping rates for Keswick Dam between July 1 and March 31 would be reduced between sunset and sunrise. Ramping rate conditions would continue under the No Action Alternative and would continue to improve conditions for winter-run Chinook salmon by minimizing stranding risk.

- **Fall and Winter Refill and Redd Maintenance:** Reclamation would maintain fall-run Chinook salmon redds in consideration of rebuilding storage and coldwater pool for the subsequent year. A risk analysis will be conducted to minimize adverse impacts to shallow late-spawning winter-run Chinook salmon redds based on the probability of sufficient coldwater in a subsequent year, and a conservative distribution and timing of subsequent winter-run Chinook salmon.

  Fall and winter refill and redd maintenance would continue under the No Action Alternative and may negatively affect the population, particularly shallow late-spawning winter-run Chinook salmon redds.

- **Spring Pulse Flows:** Reclamation would release spring pulse flows of up to 150 TAF to help spring-run Chinook salmon juvenile out-migration when the projected total May 1 Shasta Reservoir storage indicates a likelihood of sufficient cold water to support summer coldwater pool management, and the pulse does not interfere with the ability to meet performance objectives or other anticipated operations of the reservoir.

  Under the No Action Alternative, few if any winter-run Chinook salmon would be impacted and those that may be late outmigrants could possibly benefit from a spring pulse release.

- **Water Temperature Management:** Reclamation would operate the Shasta Dam TCD to provide temperature management while minimizing impacts on power generation. Reclamation would address coldwater management using a tiered strategy to target downstream water temperatures based on projected total storage and coldwater pool. The tiered strategy manages limited coldwater resources to achieve desired fisheries objectives by conserving use of the coldwater pool to when egg incubation stages have the highest dissolved oxygen (DO) demands.

  Water temperature management would continue under the No Action Alternative and resources will be managed to achieve fisheries objectives, including objectives for winter-run Chinook salmon, possibly providing a benefit.

- **Winter-Run Chinook Salmon Supplementation:** Reclamation would rely upon increased use of Livingston-Stone National Fish Hatchery (NFH) during droughts to increase production of winter-run Chinook salmon. Increased production would aim to offset temperature dependent mortality and low survival on the Sacramento River and in the Delta. Operations and maintenance of the Livingston-Stone NFH are conducted by USFWS, which Reclamation provides funding for.

Under the No Action Alternative, increased use of Livingston-Stone NFH would beneficially affect the population possibly offsetting temperature dependent mortality and low survival on the Sacramento River and in the Delta.

- **Spawning and Rearing Habitat:** The No Action Alternative reflects the 2020 Record of Decision evaluation of habitat restoration in concert with operations. The No Action Alternative includes habitat restoration projects at a programmatic level, and anticipates additional environmental documentation for required ground disturbance activities.

  Reclamation's habitat restoration programs in the Sacramento River, as well as in Clear Creek, lower American River, Stanislaus River, San Joaquin River, and the Delta will continue through separate environmental compliance and future restoration plans as independent programs. For the purpose of the analysis, these habitat restoration projects are considered independent projects that will be considered under cumulative effects.

O.3.1.2 Bay-Delta

No Action Alternative Components and Winter-run Chinook Salmon

The No Action Alternative consists of components common to all other Alternatives ("common components") and components unique to the No Action Alternative. Discussed here are all components that occur in the Bay-Delta and how operations of those components under the No Action Alternative may impact the life stages of winter-run Chinook salmon present in the system.

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on winter-run Chinook salmon include south Delta entrainment and reduced velocities within some migratory corridors. This would include operations of Old and Middle River Reverse Flow Management (OMR management) season. Seasonal operations of OMR management season may cause adverse or beneficial impacts for winter-run Chinook salmon in the Delta dependent on fish presence and distribution, and flows.

- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. This period is outside of the migration window for juvenile winter-run Chinook salmon in the Delta thus water transfers will not impact winter-run Chinook salmon.

- **Agricultural Barriers:** Few if any winter-run Chinook salmon would be expected to occur in the region of the agricultural barriers during the period when the barriers are present. Under the No Action Alternative, impacts to winter-run Chinook salmon may continue but would likely be minimal.

- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no impact on winter-run Chinook salmon as a result of the timing of the action, i.e., July 1 to August 31, avoiding the main period of winter-run Chinook salmon occurrence.

- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the Roaring River Distribution System (RRDS) would occur during the months of September through November. This period is outside of the migration window for juvenile winter-run Chinook salmon in the Delta and thus this component will not impact winter-run Chinook salmon.
- **Delta Cross Channel Gates:** Winter-run Chinook salmon are vulnerable to entrainment into the Delta Cross Channel (DCC) if they are present when the gates are open. Individuals entrained into the DCC enter the interior Delta where survival rates are lower relative to fish that remain in the main stem Sacramento River. Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to winter-run Chinook salmon from the Tracy and Skinner fish facilities would occur. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on winter-run Chinook salmon would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** Seasonal Old and Middle River reverse flow management is implemented to limit upstream flows towards the SWP and CVP pumping facilities during periods when salmonids and Delta smelt are likely to be abundant in the Delta. OMR management may be initiated by multiple environmental or fish distribution triggers, but typically begins in December or January. Flow limits may be made more restrictive or permissive based on in-season fish survey, salvage and environmental data. OMR management continues through June, or until species-specific off ramps (based on water temperatures or cumulative migration proportion) have occurred. All components of OMR management would continue under the No Action Alternative, and beneficial impacts to juvenile winter-run Chinook salmon resulting from reduced entrainment risk would continue.
- **Spring Delta Outflow:** Under the No Action Alternative, Reclamation would operate to D-1641, subject to entrainment protections. DWR would operate to the SWP 2020 Incidental Take Permit, which includes a number of export restrictions and storage of water for release at other times. Increased spring Delta outflow may improve survival for outmigrating salmonids, and any benefits for winter-run Chinook salmon would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** The Barker Slough Pumping Plant (BSPP) would continue to operate and maintain under applicable regulatory requirements and remove sediment and aquatic weeds as needed. The annual maximum diversion is 125 TAF and the maximum daily diversion rate for the BSPP is 175 cfs. Reclamation and DWR would implement Delta smelt entrainment minimization measures in coordination with USFWS. No impacts on winter-run Chinook salmon BSPP operations are anticipated, under the No Action Alternative.

- **Delta Smelt Supplementation:** Under the No Action, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation. Under the No Action Alternative, use of Delta smelt supplementation would not impact winter-run Chinook salmon.
- **Delta Smelt Summer and Fall Habitat:** Under the No Action Alternative, Reclamation and DWR would improve Delta smelt food supply and habitat through Delta smelt summer and fall habitat actions (SFHAs) that manage X2 to 80 kilometer (km) in September and October of wet and above normal years, operate the Suisun Marsh Salinity Control Gate (SMSCG) in below normal and above normal years, and undertake food enhancement actions developed through structured decision making. Under the No Action Alternative, Delta smelt summer and fall habitat actions are not expected to impact winter-run Chinook salmon as peak presence of juveniles in the Delta occurs during the spring.

O.3.2 Central Valley Spring-Run Chinook Salmon ESU

O.3.2.1 Sacramento River

No Action Alternative Components and Spring-run Chinook Salmon

The No Action Alternative consists of components common to all other Alternatives ("common components") and components unique to the No Action Alternative. Discussed here are all components that occur on the Sacramento River and how operations of those components under the No Action Alternative may impact the life stages of spring-run Chinook salmon present in the system.

- **Fall Operations and Rice Decomposition Smoothing:** Release reductions from Shasta Reservoir early in the fall and other common components, like rice decomposition smoothing, would continue under the No Action Alternative and may negatively affect the spring-run Chinook salmon population including potential adverse impacts of low flows and elevated water temperatures leading to unsuccessful out-migration.
- **Ramping Rates:** Ramping rates for Keswick Dam between July 1 and March 31 would be reduced between sunset and sunrise. Ramping rate conditions would continue under the No Action Alternative and would continue to improve conditions for spring-run Chinook salmon by minimizing stranding risk.
- **Fall and Winter Refill and Redd Maintenance:** Fall and winter refill and redd maintenance would continue under the No Action Alternative and may negatively or beneficially affect the spring-run Chinook salmon population depending on Keswick Reservoir releases to meet Shasta Reservoir End of September (EOS) storage.
- **Spring Pulse Flows:** Reclamation would release spring pulse flows of up to 150 TAF to help spring-run Chinook salmon juvenile out-migration when the projected total May 1 Shasta Reservoir storage indicates a likelihood of sufficient cold water to support summer coldwater pool management, and the pulse does not interfere with the ability to meet performance objectives or other anticipated operations of the reservoir.

Under the No Action Alternative, outmigrating juvenile and yearling spring-run Chinook salmon could benefit from a spring pulse release possibly increasing survival and decreasing travel time down the Sacramento River.

- **Water Temperature Management:** Water temperature management would continue under the No Action Alternative and resources will be managed to achieve fisheries objectives, including objectives for winter-run Chinook salmon, and suitable temperatures for spring-run Chinook salmon.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH would not impact spring-run Chinook salmon.

O.3.2.2 Clear Creek

No Action Alternative Components and Spring-run Chinook Salmon

- **Summer and Fall Operations:** During the summer and early fall, Reclamation operates to provide reservoir elevations as full as practical for recreation. Summer and fall imports help maintain Whiskeytown Reservoir elevations, provide cool water for releases to Clear Creek for water temperature control objectives, decrease residence time in Lewiston Reservoir for Trinity River temperature control, and help maintain water temperature objectives in the Sacramento River by supplying water to Keswick Reservoir.

  Summer and fall operations would continue under the No Action Alternative and may adversely or beneficially impact spring-run Chinook salmon, including potential adverse impacts of low flows and elevated water temperatures and potential beneficial impacts of cool water releases.

- **Ramping Rates:** Ramping rates for Whiskeytown Dam would be reduced to no lower than 25 cfs per hour. These requirements may be modified on a case-by-case basis during flood control. Ramping rate conditions would continue under the No Action Alternative and would continue to improve habitat for spring-run Chinook salmon by minimizing stranding risk.
- **Segregation Weir:** A segregation weir will be present late August through early November on Clear Creek between the Clear Creek Gorge Cascade and Clear Creek Road Bridge. Placement of the weir would occur before fall-run Chinook salmon enter Clear Creek to minimize hybridization with spawning spring-run Chinook salmon and redd superimposition. Removal of the weir would occur after the peak of fall-run Chinook salmon spawning when the risk of redd superimposition is very low. The weir location and timing protect most of the spring-run Chinook salmon utilizing Clear Creek, while minimizing impacts to other salmonids.

  Operation of the segregation weir currently helps alleviate some of the hybridization which has occurred between fall-run and spring-run Chinook salmon by preventing concurrent use of spawning habitat. It is anticipated that further operation of the weir under the No Action Alternative would further isolate fall-run and spring-run Chinook salmon, leading to population-level benefits.

- **Minimum Instream Flows:** Reclamation would release a minimum base flow in Clear Creek of 200 cfs from October through May and 150 cfs from June through September in all water year types except critical water year types. In critical years, Clear Creek base flows may be reduced below 150 cfs based on available water from Trinity Reservoir. Additional flow may be required for water temperature management during the fall. Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing, and migrating spring-run Chinook salmon.

- **Pulse Flows:** Reclamation would create pulse flows for both channel maintenance and spring attraction flows. For spring attraction flows, Reclamation would release 10 TAF up to the safe release capacity in all water year types except for critical water year types. For channel maintenance flows, Reclamation would release 10 TAF from Whiskeytown Dam up to the safe release capacity, in all water year types except dry and critical. Pulse flows would continue under the No Action Alternative and could attract adult spring-run Chinook salmon holding in the Sacramento mainstem encouraging movement towards spawning habitat.

- **Water Temperature Management:** Reclamation would manage Whiskeytown releases to meet a daily average water temperature of 60°F at the Igo gage from June 1 through September 15 and 56°F or less at the Igo gage from September 15 to October 31. In critical or dry water year types, Reclamation would operate as close to these water temperatures as possible. Water temperature management would continue under the No Action Alternative and may help reduce thermal stress to spring-run Chinook salmon during holding, spawning, and embryo incubation.

- **Spawning and Rearing Habitat:** The No Action Alternative reflects the 2020 Record of Decision evaluation of habitat restoration in concert with operations. The No Action Alternative includes habitat restoration projects at a programmatic level, and anticipates additional environmental documentation for required ground disturbance activities.

  Reclamation's habitat restoration programs in the Sacramento River, as well as in Clear Creek, lower American River, Stanislaus River and the Delta will continue through separate environmental compliance and future restoration plans as independent programs. For the purpose of the analysis, these habitat restoration projects are considered independent projects that will be considered under cumulative effects.

O.3.2.3 Bay-Delta

No Action Alternative Components and Spring-run Chinook Salmon

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on spring-run Chinook salmon include south Delta entrainment and reduced velocities within some migratory corridors. This would include operations of Old and Middle River Reverse Flow Management (OMR management) season. Seasonal operations of OMR management season may cause adverse or beneficial impacts for spring-run Chinook salmon in the Delta dependent on fish presence and distribution, and flows.

- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. This period is outside of the migration window for spring-run Chinook salmon in the Delta thus water transfers will not impact spring-run Chinook salmon.
- **Agricultural Barriers:** Few if any Sacramento River origin spring-run Chinook salmon would be expected to occur in the region of the agricultural barriers during the period when the barriers are present. Under the No Action Alternative, impacts to spring-run Chinook salmon may continue but would likely be minimal.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no impact on spring-run Chinook salmon as a result of the timing of the action, i.e., July 1 to August 31, avoiding the main period of spring-run occurrence.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** The RRDS flood up window is outside of the migration period for spring-run Chinook salmon in the Delta and thus this component will not impact spring-run Chinook salmon.
- **Delta Cross Channel Gates:** Spring-run Chinook salmon are vulnerable to entrainment into the Delta Cross Channel (DCC) if they are present when the gates are open. Individuals entrained into the DCC enter the interior Delta where survival rates are lower relative to fish that remain in the main stem Sacramento River. Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to spring-run Chinook salmon from the Tracy and Skinner fish facilities would occur. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on spring-run Chinook salmon would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** Seasonal Old and Middle River reverse flow management is implemented to limit upstream flows towards the SWP and CVP pumping facilities during periods when salmonids and Delta smelt are likely to be abundant in the Delta. OMR management may be initiated by multiple environmental or fish distribution triggers, but typically begins in December or January. Flow limits may be made more restrictive or permissive based on in-season fish survey, salvage and environmental data. OMR management continues through June, or until species-specific off ramps (based on water temperatures or cumulative migration proportion) have occurred.

  All components of OMR management would continue under the No Action Alternative, and beneficial impacts to juvenile spring-run Chinook salmon resulting from reduced entrainment risk would continue.

- **Spring Delta Outflow:** Under the No Action Alternative, Reclamation would operate to D-1641, subject to entrainment protections. DWR would operate to the SWP 2020 Incidental Take Permit, which includes a number of export restrictions and storage of water for release at other times. Increased spring Delta outflow may improve survival for outmigrating salmonids, and benefits for spring-run Chinook salmon would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** No impacts on spring-run Chinook salmon BSPP operations are anticipated. Under the No Action Alternative, as spring-run are not anticipated to be present in the area.
- **Delta Smelt Supplementation:** Under the No Action Alternative, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation. Under the No Action Alternative, use of Delta smelt supplementation would not impact spring-run Chinook salmon as these two species do not compete for available resources.
- **Delta Smelt Summer and Fall Habitat:** Under the No Action Alternative, Reclamation and DWR would improve Delta smelt food supply and habitat through Delta smelt summer and fall habitat actions (SFHAs) that manage X2 to 80 kilometer (km) in September and October of wet and above normal years, operate the SMSCG in below normal and above normal years, and undertake food enhancement actions developed through structured decision making. Under the No Action Alternative, Delta smelt summer and fall habitat actions are not expected to impact spring-run Chinook salmon as peak presence of juveniles occurs during the spring.

O.3.3 California Central Valley Steelhead DPS

O.3.3.1 Sacramento River

No Action Alternative Components and Steelhead

- **Seasonal Operations:** The operations of Keswick Dam vary seasonally and in response to annual hydrologic conditions. In winter, primary considerations are flood control and minimum flows in the lower river and Delta. During the spring Reclamation seeks to maximize storage while maintaining flood control capacity, but releases to maintain downstream flows may be required in drier years. Summer operational considerations include releases for temperature control, instream diversion demands, Delta outflows, Delta salinity, and exports. In the fall, Reclamation's objective is to reduce Keswick Dam releases and rebuild storage in Shasta Reservoir. Steelhead spawning is thought to be minimal in the mainstem Sacramento, but adults use the river as a migration corridor to access spawning grounds in upstream tributaries during most months of the year, and juveniles rear throughout the river year-round.

  Given year-round use of the Sacramento River by multiple life-stages of steelhead, impacts of seasonal operations of Shasta Reservoir and other common components have numerous impacts, both adverse and beneficial, on the species. All such impacts would continue under the No Action Alternative, including potential adverse impacts of low flows and elevated water temperatures.

- **Rice Decomposition Smoothing:** Reclamation will release flows based on Sacramento Valley Water Service Contractors demand and SRS Contractors coordinated rice decomposition smoothing diversion schedule. SRS Contractors and CVP Water Service Contractors will synchronize their diversions to lower peak rice decomposition demand. The delivery schedule considers dewatering risk for winter-run Chinook salmon redd locations but may also benefit rearing salmonids including steelhead.
- **Ramping Rates:** Ramping rates for Keswick Dam between July 1 and March 31 would be reduced between sunset and sunrise. Current ramping rate conditions are likely to continue to improve habitat for steelhead by minimizing stranding risk.
- **Fall and Winter Refill and Redd Maintenance:** Under the No Action Alternative Reclamation would continue to maintain fall-run Chinook salmon redds in consideration of rebuilding storage and coldwater pool for the subsequent year. Rearing juveniles and migrating adult steelhead may be impacted due to changes in Keswick Reservoir releases to meet Shasta Reservoir End of September (EOS) storage.
- **Spring Pulse Flows:** Reclamation would continue to release spring pulse flows of up to 150 TAF under the No Action Alternative to help spring-run Chinook salmon juvenile out-migration when the projected total May 1 Shasta Reservoir storage indicates a likelihood of sufficient cold water to support summer coldwater pool management, and the pulse does not interfere with the ability to meet performance objectives or other anticipated operations of the reservoir. Outmigrating steelhead may also benefit from this action under the No Action Alternative as a result of increased survival and decreasing travel time down the Sacramento River. There may be unintentional adverse impacts of spring pulse flows on spawning behavior and fry stranding from sudden drops in flow.
- **Water Temperature Management:** There may be beneficial impacts of water temperature management for adult migration and juveniles rearing through reduction of thermal stress, however, research over the last decade has identified that rivers with high, stable flows tend to favor residency (Courter et al. 2009; Kendall et al. 2015). Therefore, managed flows for winter-run Chinook salmon egg incubation may have disparate impacts on rates of steelhead anadromy.

  Water temperature management described above for winter-run Chinook salmon would continue under the No Action Alternative and resources will be managed to achieve fisheries objectives, including objectives for steelhead.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH would not impact steelhead.

O.3.3.2 Clear Creek

No Action Alternative Components and Steelhead

- **Seasonal Operations:** In the winter and spring, Whiskeytown Reservoir is operated to regulate flows for flood management. Starting in November, Reclamation will draw down Whiskeytown Reservoir by approximately 35 thousand acre-feet (TAF) to create flood management space, generally refilling in April or May. Heavy rainfall events occasionally result in uncontrolled Gloryhole Spillway discharges to Clear Creek,

through the Whiskeytown Gloryhole. During the summer and early fall, Reclamation operates to provide reservoir elevations as full as practical for recreation. Summer and fall imports help maintain Whiskeytown Reservoir elevations, provide cool water for releases to Clear Creek for water temperature control objectives, decrease residence time in Lewiston Reservoir for Trinity River temperature control, and help maintain water temperature objectives in the Sacramento River by supplying water to Keswick Reservoir.

Seasonal operations would continue under the No Action Alternative and may adversely or beneficially impact steelhead, including potential adverse impacts of low flows and elevated water temperatures and potential beneficial impacts of cool water releases.

- **Ramping Rates:** Ramping rates for Whiskeytown Dam would be reduced to no lower than 25 cfs per hour. These requirements may be modified on a case-by-case basis during flood control.
- Current ramping rate conditions are likely to continue to improve habitat for steelhead by minimizing stranding risk.
- **Segregation Weir:** Operation of the segregation weir may impede upstream migration of early arriving adult steelhead, but its removal prior to the typical initiation of spawning in December should minimize adverse impacts. Impacts would continue under the No Action Alternative.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing, and migrating steelhead.
- **Pulse Flows:** Pulse flows would continue under the No Action Alternative and could beneficially impact steelhead by attracting adult steelhead holding in the Sacramento mainstem.
- **Water Temperature Management:** Water temperature management would continue under the No Action Alternative and may help reduce thermal stress to rearing steelhead.

O.3.3.3 Lower American River

No Action Alternative Components and Steelhead

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, including: (1) operation of Folsom Reservoir in the winter primarily for flood control and minimum flows in the lower American River and Delta; (2) maximizing capture of spring runoff by filling Folsom Reservoir as close to full as possible, subject to flood control and lower river considerations; (3) releasing flows above the minimum instream flow requirements for instream temperature control, Delta outflow, and water supply during the summer; and (4) managing water temperature during the fall, balancing limited coldwater pool and storage, to maximize the ability to maintain suitable water temperatures for steelhead rearing and fall-run Chinook salmon spawning. Potential adverse and beneficial impacts on steelhead would continue under the No Action Alternative, and include the potential for redd dewatering, redd scouring, juvenile stranding, and above-optimal water temperatures in the lower river.

- **Ramping Rates:** Under the No Action Alternative ramping rates for Nimbus Dam would follow currently prescribed limits, and if possible, ramp down would occur at night. Current ramping rate conditions are likely to continue to improve habitat for steelhead by minimizing stranding risk.

- **Minimum Instream Flows:** Reclamation would implement the minimum release requirement (MRR) proposed by the Sacramento Area Water Forum in 2017, as modified by the 2020 Record of Decision, based on the month and annual hydrology. Minimum instream flows would continue under the No Action Alternative and would benefit spawning, rearing and migrating steelhead.

  Spring Pulse Flows: Reclamation will implement a spring pulse in years that the MRR for March is between 1,000 cfs and 1,500 cfs. The peak flow of the pulse flow would be three times the March MRR, even if implemented in April or May, but no higher than 4,000 cfs and lasting two days. Pulse flows would continue under the No Action Alternative, could attract adult steelhead holding in the Sacramento mainstem and facilitate downstream migration by juveniles and yearlings.

- **Redd Dewatering Adjustments:** Reclamation, through Governance, will schedule MRR releases consistent with the implementation of redd dewatering protective adjustments to limit potential redd dewatering January through May. Redd dewatering adjustments would continue under the No Action Alternative and beneficially impact egg-to-fry survival of steelhead.

- **Water Temperature Management:** Reclamation would implement the Automated Temperature Selection Procedure (ATSP), in developing the Temperature Management Plan (TMP). In critical or dry water year types, Reclamation would operate as close to these temperatures as possible.

  Under the No Action Alternative, there may be beneficial impacts of continued water temperature management for adult migration and juveniles rearing through reduction of thermal stress, however, research over the last decade has identified that rivers with high, stable flows tend to favor residency (Courter et al. 2009; Kendall et al. 2014). Therefore, managed flows may have disparate impacts on rates of steelhead anadromy.

O.3.3.4 Bay-Delta

No Action Alternative Components and Steelhead

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on steelhead include south Delta entrainment and reduced velocities within some migratory corridors. This would include operations of Old and Middle River Reverse Flow Management (OMR management) season. Seasonal operations of OMR management season may cause adverse or beneficial impacts for steelhead in the Delta dependent on fish presence, distribution, and flows.

- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. This period is outside of the juvenile emigration window for steelhead in the Delta, though year-round presence of juveniles is possible. Water transfers are not likely impact juvenile outmigrating steelhead.
- **Agricultural Barriers:** DWR would continue to operate three agricultural barriers to maintain water levels for agricultural diversions in parts of the South Delta. Most juvenile steelhead exiting from the San Joaquin River and its tributaries will have moved downstream of the barriers prior to installation, late migrants may be impacted by their construction or closure. Under the No Action Alternative, impacts to steelhead may continue but would likely be minimal.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no impact on steelhead as a result of the timing of the action, i.e., July 1 to August 31, avoiding the main period of steelhead juvenile outmigration.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the Roaring River Distribution System (RRDS) would occur during the months of September through November. This period is outside of the juvenile emigration window for steelhead in the Delta. This component is not anticipated to impact juvenile steelhead.
- **Delta Cross Channel Gates:** Fish outmigrating from the Sacramento River are vulnerable to entrainment into the Delta Cross Channel (DCC) if they are present when the gates are open. Individuals entrained into the DCC enter the interior Delta where survival rates are lower relative to fish that remain in the main stem Sacramento River. Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to steelhead from the Tracy and Skinner fish facilities would occur. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on steelhead would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** Seasonal Old and Middle River reverse flow management is implemented to limit upstream flows towards the SWP and CVP pumping facilities during periods when salmonids and Delta smelt are likely to be abundant in the Delta. OMR management may be initiated by multiple environmental or fish distribution triggers, but typically begins in December or January. Flow limits may be made more restrictive or permissive based on in-season fish survey, salvage and environmental data. OMR management continues through June, or until species-specific off ramps (based on water temperatures or cumulative migration proportion) have occurred.

All components of OMR management would continue under the No Action Alternative, and beneficial impacts to juvenile steelhead resulting from reduced entrainment risk would continue.

- **Spring Delta Outflow:** Under the No Action Alternative, Reclamation would operate to D-1641, subject to entrainment protections. DWR would operate to the SWP 2020 Incidental Take Permit, which includes a number of export restrictions and storage of water for release at other times. Increased spring outflow may improve survival for outmigrating salmonids, and benefits for early migrant steelhead would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** The BSPP would continue to operate and maintain under applicable regulatory requirements and remove sediment and aquatic weeds as needed. The annual maximum diversion is 125 TAF and the maximum daily diversion rate for the BSPP is 175 cfs. DWR would implement Delta smelt entrainment minimization measures in coordination with USFWS. No impacts on steelhead BSPP operations are anticipated.
- **Delta Smelt Supplementation:** Under the No Action Alternative, use of Delta smelt supplementation would not impact steelhead.
- **Delta Smelt Summer and Fall Habitat:** Under the No Action Alternative, Delta smelt summer and fall habitat actions are not expected to impact juvenile steelhead as peak presence occurs during the spring.

O.3.3.5 San Joaquin River

No Action Alternative and Steelhead

Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision. Steelhead primarily use the lower San Joaquin River as a migratory corridor. The No Action Alternative is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project.

O.3.3.6 Stanislaus River

No Action Alternative Components and Steelhead

- **Seasonal Operations:** In the winter and spring, Reclamation will operate to D-1641 and for flood control in accordance with the USACE Standard Operation and Maintenance Manual for the Lower San Joaquin River Levees Lower San Joaquin River and Tributaries Project, California (April 1959). Operating to flood control constraints is relatively infrequent because New Melones Reservoir is a larger reservoir relative to its annual inflow. Reclamation seeks to minimize potential redd dewatering, redd scouring, and juvenile stranding for steelhead. Potential impacts on steelhead would continue under the No Action Alternative.

During the summer, Reclamation is required to maintain applicable dissolved oxygen (DO) standards on the lower Stanislaus River for species protection. Reclamation operates to a 7.0 milligrams per liter DO requirement at Ripon from June 1 to September 30. This requirement would have a beneficial impact for juvenile steelhead rearing and adult migration. In the fall, Reclamation operates to a D-1641 fall pulse flow requirement in October for fish attraction, which may benefit adult migration.

- **Ramping Rates:** Reclamation will coordinate releases on the Stanislaus River based on prescribed ramping rates and depending on water year type. Current ramping rate conditions are likely to continue to improve habitat for steelhead by minimizing stranding risk.
- **Minimum Instream Flows:** Reclamation would operate to the New Melones Stepped Release Plan (SRP). SRP flows would be Reclamation's contribution to D-1641's Vernalis standards. Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing and migrating steelhead.
- **Winter Instability Flows:** Reclamation releases additional flow in January and February to simulate natural variability in the winter hydrograph and to enhance access to varied rearing habitats. Reclamation, through Governance, schedules the winter instability flow volume in consideration of timing flows to coincide with a natural storm event which may naturally cue juvenile outmigration. Rain events may meet the need for winter instability flows and not require additional releases. Winter instability flows would continue under the No Action Alternative, and may benefit juvenile steelhead.
- **Spring Pulse Flows:** Reclamation will release additional flows starting as early as March through as late as June. Reclamation, through Governance, will schedule spring pulse flow volumes consistent with volumes in the SRP. Spring pulse flows would continue under the No Action Alternative, and may benefit juvenile or adult steelhead.
- **Fall Pulse Flows:** Reclamation will release additional flows in October. Reclamation, through Governance, will schedule fall pulse flow volumes consistent with the volumes in the SRP. Fall pulse flows would continue under the No Action Alternative, and may benefit adult steelhead.

O.3.4 Southern DPS Green Sturgeon

Young green sturgeon appear to rear for the first one to two months in the Sacramento River between Keswick Dam and Hamilton City and rearing habitat condition and function may be affected by variation in annual and seasonal river flow and temperatures. The restriction of spawning habitat for green sturgeon to only one reach of the Sacramento River increases the vulnerability of this spawning population to catastrophic events, which is one of the primary reasons that the Southern DPS of green sturgeon was federally listed as a threatened species in 2006.

O.3.4.1 Sacramento River

No Action Alternative Components and Green Sturgeon

- **Seasonal Operations:** Green sturgeon adults and larvae are present in the Sacramento River in association with upstream spawning migrations primarily during the late spring and early summer, though both life-stages may be present into the fall at lower abundances.

  Seasonal operations and other common components would continue under the No Action Alternative and may negatively affect the population including potential adverse impacts of low flows and elevated water temperatures impacting the movement or survival of adults and larvae.

- **Rice Decomposition Smoothing**: The delivery schedule considers dewatering risk for Chinook salmon redds and may create lower flows in October and November. These actions may have an adverse impact on juveniles from low flows and elevated water temperatures.

- **Ramping Rates:** Ramping rates for Keswick Dam between July 1 and March 31 would be reduced between sunset and sunrise. Ramping rate conditions would continue under the No Action Alternative and may continue to minimizing stranding risk for green sturgeon.

- **Fall and Winter Refill and Redd Maintenance:** Fall and winter refill and redd maintenance would continue under the No Action Alternative and may adversely impact green sturgeon due to changes in Keswick Reservoir releases to meet Shasta Reservoir End of September (EOS) storage.

- **Spring Pulse Flows:** Migrating adult green sturgeon may benefit from increased flows under the No Action Alternative.

- **Water Temperature Management:** Water temperature management would continue under the No Action Alternative and resources will be managed to achieve fisheries objectives, including potential incidental benefits to adult and larval green sturgeon.

- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH would not impact green sturgeon.

O.3.4.2 San Joaquin River

Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision. It is unknown how green sturgeon use the San Joaquin River. The No Action Alternative is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project.

O.3.4.3 Bay-Delta

No Action Alternative Components and Green Sturgeon

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on green sturgeon include south Delta entrainment and reduced flow velocities within some migratory corridors. Impacts would continue under the No Action Alternative.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. Green sturgeon may benefit from increased flow velocities in Delta channels during the transfer window and impacts from entrainment at the south Delta facilities is limited due to the low occurrence of green sturgeon at the salvage facilities.
- **Agricultural Barriers:** While green sturgeon data in the southern Delta is limited, there may be adults migrating to the San Joaquin River to spawn in April, which may cause delays to migration. Impacts would continue under the No Action Alternative.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little impact on green sturgeon as a result of the minimization efforts associated with maintenance activities.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Impacts through entrainment are unlikely due to low abundance of the species, but any impacts would continue under the No Action Alternative.
- **Delta Cross Channel Gates:** Green sturgeon are vulnerable to entrainment into the DCC if they are present when the gates are open. Individuals entrained into the DCC enter the interior Delta. It is not known if survival of green sturgeon is lower in the interior Delta as has been observed for Chinook salmon. Under the No Action Alternative, operation of the DCC, and resulting probabilities of entrainment would continue.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to green sturgeon from the Tracy and Skinner fish facilities would occur. Impacts includes mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** Seasonal Old and Middle River reverse flow management is implemented to limit upstream flows towards the SWP and CVP pumping facilities during periods when salmonids and Delta smelt are likely to be abundant in the Delta. OMR management may be initiated by multiple environmental or fish distribution triggers, but typically begins in December or January. Flow limits may be made more restrictive or permissive based on in-season fish survey, salvage and environmental data. OMR management continues through June, or until species-specific off ramps (based on water temperatures or cumulative migration proportion) have occurred. All components of OMR management

would continue under the No Action Alternative, though impacts to green sturgeon are uncertain, and the presence of juvenile green sturgeon in the Delta typically continues into the summer and after OMR management has been off ramped.

- **Spring Delta Outflow:** Impacts to green sturgeon are uncertain, and juvenile green sturgeon are typically present in the Delta year-round.
- **Barker Slough Pumping Plant:** No impacts on green sturgeon BSPP operations are anticipated as they are fully screened from this facility.
- **Delta Smelt Supplementation:** Under the No Action, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with no anticipated impact on green sturgeon in the Delta.
- **Delta Smelt Summer and Fall Habitat:** Potential impacts to green sturgeon are unknown, but any impacts would continue under the No Action Alternative.

O.3.5 Delta Smelt

O.3.5.1 Bay-Delta

No Action Alternative Components and Delta Smelt

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on Delta smelt include south Delta entrainment and reduced food web productivity, and impacts on the extent of fall abiotic habitat. This would include operations of Old and Middle River Reverse Flow Management (OMR management) season and Delta Smelt Summer and Fall Habitat season.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. This period avoids the occurrence of Delta smelt in the south Delta and therefore limits entrainment and predation risk at the south Delta export facilities.
- **Agricultural Barriers:** Few if any Delta smelt would be expected to occur in the region of the agricultural barriers during the period when the barriers are present. Under the No Action Alternative, impacts to Delta smelt would be minimal.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no impact on Delta smelt as a result of the timing of the action, i.e., July 1 to August 31, avoiding the main period of potential Delta smelt entrainment into the South Delta.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** There may be potential limited impacts to Delta smelt such as entrainment.

- **Delta Cross Channel Gates:** It is unknown what, if any, direct impacts occur to Delta smelt from opening or closing the Delta Cross Channel (DCC) gate. Delta smelt occurrence is limited near the DCC. The impacts of operations of the DCC would continue and likely be minimal under the No Action Alternative.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to Delta smelt from the Tracy and Skinner fish facilities would occur. This includes mortality from pre-screen loss, predation, collection, handling, transport, and release, with a small fraction potentially surviving the salvage process (Reclamation 2019). The potential impacts from the Tracy and Skinner fish salvage facilities would be limited by continued OMR management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** Seasonal Old and Middle River reverse flow management is implemented to limit upstream flows towards the SWP and CVP pumping facilities during periods when salmonids and Delta smelt are likely to be abundant in the Delta and undergoing seasonal migration. OMR management may be initiated by multiple environmental or fish distribution triggers, but typically begins in December or January. Flow limits may be made more restrictive or permissive based on in-season fish survey, salvage and environmental data. OMR management continues through June, or until species-specific off ramps (based on water temperatures or cumulative migration proportion) have occurred.

  All components of OMR management would continue under the No Action Alternative, and beneficial impacts to adult and larval Delta smelt resulting from reduced entrainment risk would continue.
- **Spring Delta Outflow:** Increased spring outflow may increase food resources for larval Delta smelt and benefits would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** Reclamation and DWR would implement Delta smelt entrainment minimization measures in coordination with USFWS. Benefits to Delta smelt resulting from reduced entrainment risk would continue under the No Action Alternative.
- **Delta Smelt Supplementation:** Under the No Action Alternative, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation. Impacts of supplementation are currently under evaluation; however, Delta smelt Supplementation under the No Action Alternative may provide benefits to Delta smelt.
- **Delta Smelt Summer and Fall Habitat:** Under the No Action Alternative, Reclamation and DWR would improve Delta smelt food supply and habitat through Delta smelt summer and fall habitat actions (SFHAs) that manage X2 to 80 kilometers (km) in September and October of wet and above normal years, operate the SMSCG in below normal and above normal years, and undertake food enhancement actions developed through structured decision-making. Benefits to juvenile and adult Delta smelt growth and survival are anticipated, would continue under the No Action Alternative.

O.3.6 Longfin Smelt

O.3.6.1 Bay Delta

No Action Alternative Components and Longfin Smelt

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts for longfin smelt include south Delta entrainment and reduced food web productivity.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. This period avoids peak abundance of longfin smelt in the south Delta during most water year types which limits entrainment and predation risk at the south Delta export facilities.
- **Agricultural Barriers:** Few longfin smelt would be expected to occur in the region of the agricultural barriers during the period when the barriers are present. Under the No Action Alternative, impacts to longfin smelt would be minimal.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no impact on longfin smelt as a result of the timing of the action, i.e., July 1 to August 31, avoiding the avoiding the main period of potential longfin smelt entrainment into the South Delta.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** There may be potential limited impacts to longfin smelt such as entrainment.
- **Delta Cross Channel Gates:** It is unknown what, if any, direct impacts occur to longfin smelt from opening or closing the DCC gate. Longfin smelt occurrence is limited near the DCC. The impacts of operations of the DCC would continue and likely be minimal under the No Action Alternative.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to longfin smelt from the Tracy and Skinner fish facilities would occur. This includes mortality from pre-screen loss, predation, collection, handling, transport, and release, with a small fraction potentially surviving the salvage process (Bureau of Reclamation 2019). The potential impacts from the Tracy and Skinner fish salvage facilities would be limited by continued OMR management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to adult, larval and post-larval longfin smelt resulting from reduced entrainment risk would continue.
- **Spring Delta Outflow:** Increased spring outflow may increase food resources for larval and post-larval longfin smelt and facilitate downstream movements. These benefits would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** Incidental benefits to longfin smelt resulting from reduced entrainment risk would continue under the No Action Alternative.

- **Delta Smelt Supplementation:** No impacts to longfin smelt are anticipated under this components of the No Action.
- **Delta Smelt Summer and Fall Habitat:** Benefits to juvenile longfin smelt rearing in the Delta may result, and continue under the No Action Alternative.

O.3.7 Fall-run and Late Fall-run Chinook Salmon ESU

O.3.7.1 Sacramento River

No Action Alternative Components and Fall-run and Late Fall-run Chinook Salmon

- **Seasonal Operations:** Adult fall-run and late fall-run Chinook salmon use the Sacramento River as a migration corridor and as spawning grounds between September and June.

  Release reductions from Shasta Reservoir early in the fall and other common components would continue under the No Action Alternative and may impact the fall-run and late fall-run Chinook salmon population. These include potential adverse impacts of low flows and elevated water temperatures leading to unsuccessful out-migration, and beneficial impacts of redd dewatering minimization and stabilization through egg and alevin incubation.

- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for Chinook salmon redds and may also benefit rearing fall-run and late fall-run Chinook salmon. Release reductions in October and November are intended to minimize fall-run fry stranding and redd dewatering, however, as flows drop in the river it may lead to potential adverse impacts of low flows and elevated water temperatures for fall-run and late fall-run Chinook salmon.

- **Ramping Rates:** Benefits to fall-run and late fall-run Chinook salmon would continue under the No Action Alternative by minimizing stranding risk.

- **Fall and Winter Refill and Redd Maintenance:** Reclamation would maintain fall-run Chinook salmon redds in consideration of rebuilding storage and coldwater pool for the subsequent year.

  Fall and winter refill and redd maintenance would continue under the No Action Alternative and may adversely impact fall-run and late fall-run Chinook salmon population if storage volume is below 3.2 MAF and beneficially impact when storage volume is above 3.2 MAF, as peak spawning flow is expected to occur 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

- **Spring Pulse Flows:** Under the No Action Alternative, outmigrating fall-run and late fall-run Chinook salmon could also benefit from a spring pulse release possibly increasing survival and decreasing travel time down the Sacramento River. There may be unintentional adverse impacts of spring pulse flows on late fall-run Chinook salmon spawning behavior and fry stranding for both fall-run and late fall-run Chinook salmon from sudden drops in flow.

- **Water Temperature Management:** Water temperature management would continue under the No Action Alternative and resources will be managed to achieve fisheries objectives, including objectives for fall-run and late fall-run Chinook salmon, possibly providing benefits.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH would not impact fall-run and late fall-run Chinook salmon.

O.3.7.2 Clear Creek

No Action Alternative Components and Fall-run and Late Fall-run Chinook Salmon

- **Summer and Fall Operations:** During the summer and early fall, Reclamation operates to provide reservoir elevations as full as practical for recreation. Summer and fall imports help maintain Whiskeytown Reservoir elevations, provide cool water for releases to Clear Creek for water temperature control objectives, decrease residence time in Lewiston Reservoir for Trinity River temperature control, and help maintain water temperature objectives in the Sacramento River by supplying water to Keswick Reservoir.

  Summer and fall operations would continue under the No Action Alternative and may adversely or beneficially impact fall-run and late fall-run Chinook salmon, including potential adverse impacts of low flows and elevated water temperatures and potential beneficial impacts of cool water releases.

- **Ramping Rates:** Benefits to fall-run and late fall-run Chinook salmon would continue under the No Action Alternative by minimizing stranding risk.
- **Segregation Weir:** Operation of the segregation weir currently helps alleviate some of the hybridization which has occurred between fall-run and spring-run Chinook salmon by preventing concurrent use of spawning habitat. It is anticipated that further operation of the weir under the No Action Alternative will continue to isolate fall-run and spring-run Chinook salmon, possibly reducing available fall-run Chinook salmon habitat.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing, and migrating fall-run and late fall-run Chinook salmon.
- **Pulse Flows:** Pulse flows would continue under the No Action Alternative and benefit fall-run and late fall-run Chinook salmon through improved habitat and more natural migration cues.
- **Water Temperature Management:** Water temperature management would continue under the No Action Alternative and may help reduce thermal stress to fall-run and late fall-run Chinook salmon during holding, spawning, and embryo incubation.

O.3.7.3 Lower American River

No Action Alternative Components and Fall-run Chinook Salmon

- **Seasonal Operations:** Reclamation will ramp down to the revised minimum flows from Folsom Reservoir as soon as possible in the fall and maintain these flows through fall-run Chinook salmon spawning and egg emergence, where possible, to minimize redd dewatering and juvenile stranding. Potential adverse and beneficial impacts on fall-run Chinook salmon would continue under the No Action Alternative, and include the potential for redd dewatering, redd scouring, juvenile stranding above-optimal water temperatures in the lower river.
- **Ramping Rates:** Beneficial impacts to fall-run Chinook salmon would continue under the No Action Alternative by minimizing stranding risk.
- **Minimum Instream Flows:** Minimum instream flows would continue as under the No Action Alternative and could benefit spawning, rearing and migrating fall-run Chinook salmon.
- **Spring Pulse Flows:** Pulse flows would continue under the No Action Alternative, could benefit fall-run Chinook salmon by facilitating juvenile downstream migration.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and beneficially impact egg-to-fry survival of fall-run Chinook salmon.
- **Water Temperature Management:** Water temperature management would continue under the No Action Alternative and may help reduce thermal stress to rearing and migrating fall-run Chinook salmon.

O.3.7.4 Stanislaus River

No Action Alternative Components and Fall-run Chinook Salmon

- **Seasonal Operations:** Reclamation seeks to minimize potential redd dewatering, redd scouring, and juvenile stranding for fall-run Chinook salmon. Potential adverse and beneficial impacts on fall-run Chinook salmon would continue under the No Action Alternative. In the fall, Reclamation operates to a D-1641 fall pulse flow requirement in October for fish attraction which may benefit fall-run Chinook salmon adult migration.
- **Ramping Rates:** Benefits to fall-run Chinook salmon would continue under the No Action Alternative by minimizing stranding risk.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing and migrating fall-run Chinook salmon.
- **Winter Instability Flows:** Winter instability flows would continue under the No Action Alternative, and may benefit rearing fall-run Chinook salmon by simulating natural variability in the winter hydrograph and enhancing access to varied rearing habitats.

- **Spring Pulse Flows:** Spring pulse flows would continue under the No Action Alternative, and may benefit migrating juvenile fall-run Chinook salmon.
- **Fall Pulse Flows:** Reclamation will release additional flows in October. Reclamation, through Governance, will schedule fall pulse flow volumes consistent with the volumes in the SRP.

  Fall pulse flows would continue under the No Action Alternative, and may benefit adult fall-run Chinook salmon attraction.

O.3.7.5 San Joaquin River

No Action Alternative and Fall-run Chinook Salmon

Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision. Fall-run Chinook salmon primarily use the lower San Joaquin River as a migratory corridor. The No Action Alternative is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project.

O.3.7.6 Bay-Delta

No Action Alternative Components and Fall-run and Late Fall-run Chinook Salmon

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on fall-run and late fall-run Chinook salmon include south Delta entrainment and reduced velocities within some migratory corridors. This would include operations of Old and Middle River Reverse Flow Management (OMR management) season. Seasonal operations of OMR management season may cause adverse or beneficial impacts for fall-run and late fall-run Chinook salmon in the Delta dependent on fish presence, distribution, and flows.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. This period is outside of the peak outmigration window for fall-run and late fall-run Chinook salmon in the Delta.
- **Agricultural Barriers:** Few Sacramento River origin fall-run and late fall-run Chinook salmon would be expected to occur in the region of the agricultural barriers. Most fall-run and late fall-run exiting from the San Joaquin River and its tributaries will have moved downstream of the barriers prior to installation, but some fall-run juvenile migrants may be impacted by their construction or closure. Impacts would remain unchanged under the No Action Alternative during the period when the barriers are present.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no impacts on fall-run and late fall-run Chinook salmon as a result of the timing of the action, i.e., July 1 to August 31, avoiding the main period of fall-run and late fall-run occurrence.

- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** The RRDS floor up period under the No Action is outside of the juvenile migration window for fall-run Chinook salmon in the Delta, but within the late fall-run migration window, and may impact late fall-run Chinook salmon entering the ocean between October and November.
- **Delta Cross Channel Gates:** Fall-run and late fall-run Chinook salmon are vulnerable to entrainment into the Delta Cross Channel (DCC) if they are present when the gates are open. Individuals entrained into the DCC enter the interior Delta where survival rates are lower relative to fish that remain in the main stem Sacramento River. Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, fall-run and late fall-run Chinook salmon mortality from pre-screen loss, collection, handling, transport, and release would occur. The potential impacts from the Tracy and Skinner fish salvage facilities would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to juvenile fall-run and late fall-run Chinook salmon resulting from reduced entrainment risk would continue.
- **Spring Delta Outflow:** Increased spring Delta outflow may improve survival for outmigrating salmonids, and any benefits for fall-run and late fall-run Chinook salmon would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** No impacts on fall-run and late fall-run Chinook salmon BSPP operations are anticipated.
- **Delta Smelt Supplementation:** Under the No Action Alternative, use of Delta smelt supplementation would not impact fall-run and late fall-run Chinook salmon in the Delta.
- **Delta Smelt Summer and Fall Habitat:** Under No Action Alternative, Delta smelt summer and fall habitat actions would not impact fall-run and late fall-run Chinook salmon as peak presence of juveniles occurs in the spring.

O.3.8 White Sturgeon

O.3.8.1 Sacramento River

No Action Alternative Components and White Sturgeon

- **Seasonal Operations:** Given use of the Sacramento River by multiple life-stages of white sturgeon, primarily from April through July, impacts of seasonal operations of Shasta Reservoir and other common components have numerous impacts, both adverse and beneficial on the species. All such impacts would continue under the No Action Alternative, including potential adverse impacts of low flows and elevated water temperatures.

- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for Chinook salmon redds and may create lower flows in October and November. These actions are not expected to impact on white sturgeon, as these months are outside the period of spawning to juvenile emigration. Sturgeon have not been captured during these months at the RBDD rotary screw traps from 1994-2023 (Voss 2024).
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for white sturgeon by minimizing stranding risk.
- **Fall and Winter Refill and Redd Maintenance:** Under the No Action Alternative Reclamation would continue to maintain fall-run Chinook salmon redds in consideration of rebuilding storage and coldwater pool for the subsequent year. White sturgeon may be adversely impacted by these actions when storage volume is low.
- **Spring Pulse Flows:** Migrating adult white sturgeon may benefit from increased flows under the No Action Alternative.
- **Water Temperature Management:** There may be beneficial impacts of water temperature management in the summer for white sturgeon egg incubation but the majority of benefits would be in the summer and fall for juvenile rearing through reduction of thermal stress.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH would not directly impact white sturgeon.

O.3.8.2 Lower American River

No Action Alternative Components and White sturgeon

- **Seasonal Operations:** Potential impacts on white sturgeon under the No Action Alternative the potential for juvenile stranding and above-optimal water temperatures in the lower American River.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for white sturgeon by minimizing stranding risk.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing and migrating white sturgeon.
- **Spring Pulse Flows:** Migrating adult white sturgeon may benefit from increased flows.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and beneficially impact larval survival of white sturgeon in the spring.
- **Water Temperature Management:** Under the No Action Alternative, there may be beneficial impacts of continued water temperature management for white sturgeon adult migration and juveniles rearing through reduction of thermal stress.

O.3.8.3 San Joaquin River

No Action Alternative and White Sturgeon

Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision. The No Action Alternative is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project.

O.3.8.4 Bay-Delta

No Action Alternative Components and White Sturgeon

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on white sturgeon include south Delta entrainment and reduced velocities within some migratory corridors. This would include operations of Old and Middle River Reverse Flow Management (OMR management) season. Seasonal operations of OMR management season may cause adverse or beneficial impacts for white sturgeon in the Delta dependent on fish presence, distribution, and flows.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. White sturgeon may benefit from increased flow velocities in Delta channels during the transfer window and impacts from entrainment at the south Delta facilities is limited due to the low occurrence of white sturgeon at the salvage facilities.
- **Agricultural Barriers:** DWR would continue to operate three agricultural barriers to maintain water levels for agricultural diversions in parts of the south Delta. Most adult white sturgeon migrating upstream into the San Joaquin River and its tributaries will have moved prior to installation, but late migrants may be impacted by their construction or closure. Under the No Action Alternative, impacts to white sturgeon may continue but would likely be minimal.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have a minor impact on white sturgeon as a result of the minimization efforts associated with maintenance activities.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the RRDS is outside of the migration window for white sturgeon in the Delta, but may impact resident adult and sub-adult white sturgeon.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.

- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to white sturgeon from the Tracy and Skinner fish facilities include mortality from pre-screen loss, collection, handling, transport, and release. These impacts would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to juvenile white sturgeon resulting from reduced entrainment risk would be unchanged.
- **Spring Delta Outflow:** Migrating adult white sturgeon may benefit from increased flows under the No Action Alternative.
- **Barker Slough Pumping Plant:** No impacts on white sturgeon BSPP operations are anticipated under the No Action Alternative.
- **Delta Smelt Supplementation:** Under the No Action, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with no anticipated impact on white sturgeon in the Delta.
- **Delta Smelt Summer and Fall Habitat:** Potential impacts to white sturgeon from this action under the No Action Alternative are unknown.

O.3.9 Native Minnows

O.3.9.1 Sacramento River

No Action Alternative Components and Native Minnows

- **Seasonal Operations:** Given year-round use of the Sacramento River by multiple life-stages of native minnows, impacts of seasonal operations of Shasta Reservoir and other common components have numerous impacts, both adverse and beneficial on the species. All such impacts would continue under the No Action Alternative, including potential adverse impacts of low flows and elevated water temperatures.
- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for Chinook salmon redds and may create lower flows in October and November. These actions may have an adverse impact from low flows and elevated water temperatures.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for native minnows by minimizing stranding risk.
- **Fall and Winter Refill and Redd Maintenance:** Native minnows may be benefit when storage volume is high; and be negatively impacted when storage volume is low.
- **Spring Pulse Flows:** Pulse flows may secondarily have adverse and beneficial impacts on hardhead, beneficial impacts on Sacramento hitch, and negligible impacts on Sacramento splittail. Elevated spring flows may increase hardhead spawning success (Moyle et al. 2015), however, juveniles emerging in the spring may not be able to perform in cold water and/or high flow velocities (Fangue et al. 2015). Spawning

requirements for Sacramento hitch are not well documented, but spawning is believed to take place after flows increase in response to spring rains (Moyle et al. 2015). Pulse flows are also known to increase susceptibility of hardhead juveniles to displacement and stranding (Chun et al. 2011). Sacramento splittail spawning migration occurs in the winter, therefore impacts of spring pulse flows are likely to be negligible under the No Action Alternative.

- **Water Temperature Management:** There may be beneficial impacts of water temperature management under the No Action Alternative in the early summer for hardhead spawning through reduction of thermal stress. Impacts to Sacramento splittail and hitch are likely negligible, as they have a wider range of water temperature tolerances.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH would not directly impact native minnows.

O.3.9.2 Clear Creek

No Action Alternative Components and Hardhead

- **Seasonal Operations:** Seasonal operations would continue under the No Action Alternative and may adversely or beneficially impact hardhead, including potential adverse impacts of low flows and elevated water temperatures and potential beneficial impacts of cool water releases.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for hardhead by minimizing stranding risk.
- **Segregation Weir:** Operation of the segregation weir is not expected to impact hardhead migration, as spawning primarily occurs in April and May.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing, and migrating hardhead.
- **Pulse Flows:** Pulse flows may secondarily have adverse and beneficial impacts on hardhead. Elevated spring flows may increase hardhead spawning success (Moyle et al. 2015), however, juveniles emerging in the spring may not be able to perform in cold water and/or high flow velocities (Fangue et al. 2015). Pulse flows are also known to increase susceptibility of juveniles to displacement and stranding (Chun et al. 2011).
- **Water Temperature Management:** Water temperature management would continue under the No Action Alternative and may help reduce thermal stress to hardhead.

O.3.9.3 Lower American River

No Action Alternative Components and Native Minnows

- **Seasonal Operations:** Potential impacts on native minnows would continue under the No Action Alternative, and include the potential for dewatering, juvenile stranding, and above-optimal water temperatures in the lower American River.

- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for Sacramento splittail and hardhead by minimizing stranding risk.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing and migrating Sacramento splittail and hardhead.
- **Spring Pulse Flows:** Pulse flows may secondarily have adverse and beneficial impacts on hardhead and negligible impacts on Sacramento splittail. Elevated spring flows may increase hardhead spawning success (Moyle et al. 2015), however, juveniles emerging in the spring may not be able to perform in cold water and/or high flow velocities (Fangue et al. 2015). Pulse flows are also known to increase susceptibility of hardhead juveniles to displacement and stranding (Chun et al. 2011). Sacramento splittail spawning migration occurs in the winter, therefore impacts of spring pulse flows are likely to be negligible under the No Action Alternative.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and beneficially impact egg and larval survival of Sacramento splittail and hardhead in the spring.
- **Water Temperature Management:** Under the No Action Alternative, there may be beneficial impacts of continued water temperature management for hardhead through reduction of thermal stress. Water temperature related impacts on Sacramento splittail are likely negligible due to their wide range of temperature tolerances for spawning (DWR 2004c).

O.3.9.4 Stanislaus River

No Action Alternative Components and Hardhead

- **Seasonal Operations:** Reclamation seeks to minimize impacts on the early life stages of salmonids through changes in operations below New Melones Reservoir, which may secondarily adversely impact or benefit hardhead. Potential adverse and beneficial impacts on hardhead would continue under the No Action Alternative.

  During the summer, Reclamation is required to maintain applicable dissolved oxygen (DO) standards on the lower Stanislaus River for species protection. Reclamation operates to a 7.0 milligrams per liter DO requirement at Ripon from June 1 to September 30. This requirement would have a beneficial impact on hardhead.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for hardhead by minimizing stranding risk.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing and migrating hardhead.
- **Winter Instability Flows:** Winter instability flows would continue under the No Action Alternative, and may secondarily benefit hardhead by simulating natural variability in the winter hydrograph and enhancing access to varied habitats.

- **Spring Pulse Flows:** Pulse flows may secondarily have adverse and beneficial impacts on hardhead. Elevated spring flows may increase hardhead spawning success (Moyle et al. 2015), however, juveniles emerging in the spring may not be able to perform in cold water and/or high flow velocities (Fangue et al. 2015). Pulse flows are also known to increase susceptibility of juveniles to displacement and stranding (Chun et al. 2011).
- **Fall Pulse Flows:** Fall pulse flows may secondarily adversely impact juvenile hardhead. Hardhead spawned in the spring may still be in the size range that is impacted by high velocities and pulse flows.

O.3.9.5 San Joaquin River

No Action Alternative and Native Minnows

Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision. The No Action Alternative is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project.

O.3.9.6 Bay-Delta

No Action Alternative Components and Native Minnows

- **Seasonal Operations:** Seasonal operations of OMR management season may cause adverse or beneficial impacts for native minnows in the Delta dependent on fish presence, distribution, and flows.
- **Water Transfers:** Water transfers are not likely to impact migrating native minnows as most migrations are expected to occur in the spring.
- **Agricultural Barriers:** Under the No Action Alternative, adverse impacts to native minnow migration and predation may continue but would likely be minimal.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative is expected to have a minor impact on native minnows as a result of the minimization efforts associated with maintenance activities.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the Roaring River RRDS would occur outside of the migration window for native minnows in the Delta.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, mortality from pre-screen loss, collection, handling, transport, and release would occur. The potential impacts from the Tracy and Skinner fish salvage facilities on native minnows would be limited by continued management.

- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to native minnows resulting from reduced entrainment risk would continue.
- **Spring Delta Outflow:** Increased spring outflow may improve survival through faster travel times for migrating native minnows.
- **Barker Slough Pumping Plant:** No impacts on native minnows from BSPP operations are anticipated.
- **Delta Smelt Supplementation:** Under the No Action, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with no anticipated impact on native minnows in the Delta.
- **Delta Smelt Summer and Fall Habitat:** Under the No Action Alternative, Delta smelt summer and fall habitat actions may beneficially impact adult and juvenile migration through faster travel times in the Delta.

O.3.10 Pacific Lamprey

O.3.10.1 Trinity River

Habitat conditions for Pacific lamprey in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases would continue to include natural hydrograph elements that promote life-stage specific habitat attributes. Under the No Action Alternative, the flow regime including peak flows is expected to maintain favorable habitat elements for Pacific lamprey spawning, rearing, and out-migration. While there is no difference in the implementation of the variable annual flow regime between the No Action Alternative and current conditions, the synergistic impact of these flows interacting with the channel's morphological conditions and restoration actions into the future is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for Pacific lamprey under the No Action Alternative compared to current conditions.

Spawning and Egg Incubation

Potential Changes to Pacific Lamprey from Seasonal Operations

Seasonal operations in the Trinity River are expected to maintain suitable habitat conditions for Pacific lamprey spawning and egg incubation under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish, including Pacific lamprey. Monthly average flows from March through July would be at or above 300 cfs in all water year types to provide runs, riffles, pools, and suitable temperatures for Pacific lamprey throughout the spawning and incubation period, including March through June when peak spawning occurs.

Modeled monthly average flows under the No Action Alternative would generally maintain modeled monthly average water temperatures in the Trinity River below Lewiston Dam cooler than the suggested upper limit of 64°F water temperature for spawning Pacific lamprey for Normal and wetter water year types and exceed 64°F for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The 61.7°F water temperature objective recommended by TRRP scientists to support salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would also support Pacific lamprey spawning and egg incubation temperature thresholds and likely be met under the No Action Alternative through July at Douglas City but would not be met at the North Fork Trinity River confluence in June of drier water year types or in July of all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the Pacific lamprey spawning and egg incubation period at downstream locations in some water year types under the No Action Alternative, water temperatures and the potential impacts on Pacific lamprey would not differ from current conditions.

Ammocoete Rearing and Emigration

Potential Changes to Pacific Lamprey from Seasonal Operations

Seasonal operations in the Trinity River are expected to maintain suitable habitat conditions for Pacific lamprey larval and macrophthalmia rearing and emigration under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows would be at or above 300 cfs in all water year types to provide a range of suitable depths and velocities, and water temperatures to support larval and macropthalmia rearing. Average flows from fall through spring when macropthalmia stage Pacific lamprey typically emigrate to the ocean and estuary would likewise be at or above 300 cfs in all water year types to provide depths and velocities suitable for downstream movement.

Monthly average flow under the No Action Alternative would generally maintain monthly average water temperatures in the Trinity River below Lewiston Dam below the recommended 83°F upper recommended water temperature objective for Pacific lamprey for Normal and wetter water year types and for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Year-round temperatures under the No Action Alternative would be generally suitable but cooler temperatures could have minor impacts on reduced growth rates for ammocoete rearing and emigration periods.

Adult Upstream Migration and Holding

Potential Changes to Pacific Lamprey from Seasonal Operations

Seasonal operations in the Trinity River are expected to maintain suitable habitat conditions for adult Pacific lamprey upstream migration and holding under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from December to June when adult Pacific lamprey are typically immigrating and holding would be at or above 300 cfs in all water year types to provide a range of suitable depth and velocity for upstream passage and holding areas with suitable interstitial spaces.

Monthly average flow under the No Action Alternative would generally maintain monthly average water temperatures in the Trinity River below Lewiston Dam below the recommended 84°F upper recommended water temperature objective for Pacific lamprey for Normal and wetter water year types and for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Year-round temperatures under the No Action Alternative would be generally suitable but cooler temperatures could have minor impacts on reduced growth rates for adult upstream migration and holding.

O.3.10.2 Sacramento River

No Action Alternative Components and Pacific Lamprey

- **Seasonal Operations:** Given year-round use of the Sacramento River by multiple life-stages of Pacific lamprey, impacts of seasonal operations of Shasta Reservoir and other common components like rice decomposition smoothing have numerous impacts, both adverse and beneficial, on the species. All such impacts would continue under the No Action Alternative, including potential adverse impacts of low flows and elevated water temperatures.
- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for Chinook salmon redds and may create lower flows in October and November. These actions may have an adverse impact on macropthalmia from low flows and elevated water temperatures.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for Pacific lamprey by minimizing stranding risk.
- **Fall and Winter Refill and Redd Maintenance:** The impacts to Pacific lamprey may be beneficial when storage volume is high; and adverse when storage volume is low.
- **Spring Pulse Flows:** Migrating adult Pacific lamprey and outmigrating juvenile (macropthalmia) may also benefit from this action under the No Action Alternative as a result of increased survival and decreasing travel time.
- **Water Temperature Management:** There may be beneficial impacts of water temperature management in the summer and early fall for egg incubation and rearing through reduction of thermal stress.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH could be beneficial through more prey availability for Pacific lamprey.

O.3.10.3 Clear Creek

No Action Alternative Components and Pacific Lamprey

- **Seasonal Operations:** Seasonal operations would continue under the No Action Alternative and may adversely or beneficially impact Pacific lamprey, including potential adverse impacts of low flows and elevated water temperatures and potential beneficial impacts of cool water releases.

- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for Pacific lamprey by minimizing stranding risk.
- **Segregation Weir:** Operation of the segregation weir may impede downstream migration of macropthalmia Pacific lamprey in the fall, but its removal prior to the typical initiation of spawning in December should minimize adverse impacts under the No Action Alternative.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing, and migrating Pacific lamprey.
- **Pulse Flows:** Pulse flows would continue under the No Action Alternative and may benefit Pacific lamprey by attracting adults holding in the Sacramento mainstem.
- **Water Temperature Management:** Water temperature management would continue under the No Action Alternative and may help reduce thermal stress to Pacific lamprey.

O.3.10.4 Lower American River

No Action Alternative Components and Pacific Lamprey

- **Seasonal Operations:** Potential adverse and/or beneficial impacts on Pacific lamprey would continue under the No Action Alternative. Potential secondary adverse impacts include redd dewatering, redd scouring, juvenile stranding, and above-optimal water temperatures in the lower river. Potential secondary beneficial impacts include cool water releases to maintain suitable water temperatures for steelhead rearing and fall-run Chinook salmon spawning.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for Pacific lamprey by minimizing stranding risk.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing, and migrating Pacific lamprey.
- **Spring Pulse Flows:** Pulse flows would continue under the No Action Alternative, could attract adult Pacific lamprey holding in the Sacramento mainstem and facilitate downstream migration by macropthalmia.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and beneficially impact egg and larval survival of Pacific lamprey in the spring.
- **Water Temperature Management:** Under the No Action Alternative, there may be beneficial impacts of continued water temperature management for adult migration and juveniles rearing through reduction of thermal stress.

O.3.10.5 Stanislaus River

No Action Alternative Components and Pacific Lamprey

- **Seasonal Operations:** Reclamation seeks to minimize potential redd dewatering, redd scouring, and stranding for salmonids which will secondarily benefit macropthalmia/ammocoetes by reducing stranding risk. Potential impacts on Pacific lamprey would continue under the No Action Alternative.

  Reclamation operates to a 7.0 milligrams per liter DO requirement at Ripon from June 1 to September 30. This requirement would have a beneficial impact for Pacific lamprey ammocoete rearing, late macropthalmia migrants, and early adult migrants.

  In the fall, Reclamation operates to a D-1641 fall pulse flow requirement in October for fish attraction which may benefit adult migration.

- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for Pacific lamprey by minimizing stranding risk.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing and migrating Pacific lamprey.
- **Winter Instability Flows:** Winter instability flows would continue under the No Action Alternative, and may benefit juvenile Pacific lamprey when the pulse is scheduled to coincide with a natural storm event, which may naturally cue outmigration.
- **Spring Pulse Flows:** Spring pulse flows would continue under the No Action Alternative, and may benefit macropthalmia and adult Pacific lamprey.
- **Fall Pulse Flows:** Fall pulse flows would continue under the No Action Alternative, and may benefit early migrating adult Pacific lamprey.

O.3.10.6 San Joaquin River

No Action Alternative and Pacific Lamprey

Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision. The No Action Alternative is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project.

O.3.10.7 Bay-Delta

No Action Alternative Components and Pacific Lamprey

- **Seasonal Operations:** operations of OMR management season may cause adverse or beneficial impacts for Pacific lamprey in the Delta dependent on fish presence, distribution, and flows.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. This period is outside of the macropthalmia emigration window for Pacific lamprey in the Delta. Water transfers are not likely to impact emigrating macropthalmia but may impact migrating adults in the fall.

- **Agricultural Barriers:** Most macropthalmia exiting from the San Joaquin River and its tributaries will have moved downstream of the barriers prior to installation, late migrants may be impacted through delays to migration by their construction or closure. Under the No Action Alternative, impacts to Pacific lamprey may continue but would likely be minimal.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have negligible impact on Pacific lamprey as a result of the timing of the action, i.e., July 1 to August 31, avoiding the main period of Pacific lamprey juvenile outmigration.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for RRDS would occur outside of the macropthalmia emigration window for Pacific lamprey in the Delta but may impact migrating adults.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to Pacific lamprey from the Tracy and Skinner fish facilities would occur including mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on Pacific lamprey would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to juvenile Pacific lamprey resulting from reduced entrainment risk would be unchanged.
- **Spring Delta Outflow:** Increased spring outflow may improve survival for outmigrating macropthalmia, and benefits for early migrant adult Pacific lamprey would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** No impacts on Pacific lamprey from BSPP operations are anticipated.
- **Delta Smelt Supplementation:** Under the No Action Alternative, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with no anticipated impact on Pacific lamprey in the Delta.
- **Delta Smelt Summer and Fall Habitat:** Under the No Action Alternative, Delta smelt summer and fall habitat actions may beneficially impact the beginning of adult migration and macropthalmia emigration in the fall through faster travel times in the Delta with increased river discharge (Keefer et al. 2009).

O.3.11 Western River Lamprey

O.3.11.1 Sacramento River

No Action Alternative Components and Western River Lamprey

- **Seasonal Operations:** Given year-round use of the Sacramento River by multiple life-stages of Western river lamprey, impacts of seasonal operations of Shasta Reservoir and other common components have numerous impacts, both adverse and beneficial on the species. All such impacts would remain the same under the No Action Alternative, including potential adverse impacts of low flows and elevated water temperatures.
- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for Chinook salmon redds and may create lower flows in October and November. These actions are not expected to impact Western river lamprey as these months are outside the spawning and macropthalmia outmigration window.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for Western river lamprey by minimizing stranding risk.
- **Fall and Winter Refill and Redd Maintenance:** The impacts to Western river lamprey may be beneficial when storage volume is high; and adverse when storage volume is low.
- **Spring Pulse Flows:** Migrating adult Western river lamprey and outmigrating juveniles may also benefit from this action under the No Action Alternative as a result of increased survival and decreasing travel time.
- **Water Temperature Management:** There may be beneficial impacts of water temperature management in the summer and early fall for egg incubation and rearing through reduction of thermal stress.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH could be beneficial through more food availability for Western river lamprey.

O.3.11.2 Lower American River

No Action Alternative Components and Western River Lamprey

- **Seasonal Operations:** Potential adverse and/or beneficial impacts on Western river lamprey would continue under the No Action Alternative. Potential secondary adverse impacts include the potential for redd dewatering, redd scouring, juvenile stranding, and above-optimal water temperatures in the lower river. Potential secondary beneficial impacts include cool water releases to maintain suitable water temperatures for steelhead rearing and fall-run Chinook salmon spawning.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for Western river lamprey by minimizing stranding risk.

- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing and migrating Western River lamprey.
- **Spring Pulse Flows:** Pulse flows would continue under the No Action Alternative, could attract adult Western river lamprey holding in the Sacramento mainstem and facilitate downstream migration by juveniles.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and beneficially impact egg and larval survival of Western river lamprey in the spring.
- **Water Temperature Management:** Under the No Action Alternative, there may be beneficial impacts of continued water temperature management for adult migration and juveniles rearing through reduction of thermal stress.

O.3.11.3 Stanislaus River

No Action Alternative Components and Western River Lamprey

- **Seasonal Operations:** In the winter and spring, Reclamation will operate to D-1641 and for flood control in accordance with the USACE Standard Operation and Maintenance Manual for the Lower San Joaquin River Levees Lower San Joaquin River and Tributaries Project, California (April 1959). Operating to flood control constraints is relatively infrequent because New Melones Reservoir is a larger reservoir relative to its annual inflow. Reclamation seeks to minimize potential redd dewatering, redd scouring, and stranding for salmonids which may secondarily benefit Western river lamprey. Potential impacts on Western river lamprey would continue under the No Action Alternative.

  Reclamation operates to a 7.0 milligrams per liter DO requirement at Ripon from June 1 to September 30. This requirement would have a beneficial impact for Western River lamprey ammocoete rearing, juvenile migrants, and early adult migrants.

  In the fall, Reclamation operates to a D-1641 fall pulse flow requirement in October for fish attraction which may benefit adult migration.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to improve habitat for Western river lamprey by minimizing stranding risk.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning, rearing and migrating Western river lamprey.
- **Winter Instability Flows:** Winter instability flows would continue under the No Action Alternative, and may benefit juvenile and adult Western River lamprey.
- **Spring Pulse Flows:** Spring pulse flows would continue under the No Action Alternative, and may benefit juvenile and adult Western river lamprey.

- **Fall Pulse Flows:** Fall pulse flows would continue under the No Action Alternative, and may benefit migrating adult Western River lamprey.

O.3.11.4 San Joaquin River

No Action Alternative and Western River Lamprey

Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision. The No Action Alternative is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project.

O.3.11.5 Bay-Delta

No Action Alternative Components and Western River Lamprey

- **Seasonal Operations:** Seasonal operations of OMR management season may cause adverse or beneficial impacts for Western river lamprey in the Delta dependent on fish presence, distribution, and flows.
- **Water Transfers:** Water transfers may impact emigrating Western river lamprey juveniles and may impact migrating adults in the fall.
- **Agricultural Barriers:** Western river lamprey juveniles exiting in late spring and adults migrating in the fall to/from the San Joaquin River and its tributaries may be impacted by their construction or closure.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have negligible impacts on Western river lamprey as a result of the timing of the action, i.e., July 1 to August 31, avoiding the main period of Western river lamprey juvenile outmigration and adult migration.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the RRDS would occur outside of the juvenile emigration window for Western River lamprey in the Delta but may impact migrating adults.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to Western river lamprey from the Tracy and Skinner fish facilities would occur, including mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on Western river lamprey would be limited by continued management under the No Action Alternative.

- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to juvenile Western river lamprey resulting from reduced entrainment risk would be unchanged.
- **Spring Delta Outflow:** Increased spring outflow may improve survival and travel times for outmigrating juveniles and migrating adults (Keefer et al. 2009), and any benefits for Western River lamprey would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** No impacts on Western river lamprey from BSPP operations are anticipated.
- **Delta Smelt Supplementation:** Under the No Action Alternative, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with no anticipated impact on Western river lamprey in the Delta.
- **Delta Smelt Summer and Fall Habitat:** Under the No Action Alternative, Delta smelt summer and fall habitat actions may beneficially impact the beginning of adult migration and juvenile emigration in the fall through faster travel times in the Delta with increased river discharge (Keefer et al. 2009).

O.3.12 Striped Bass

O.3.12.1 Sacramento River

No Action Alternative Components and Striped Bass

- **Seasonal Operations:** Given year-round use of the Sacramento River by multiple life-stages of striped bass, impacts of seasonal operations of Shasta Reservoir and other common components have numerous impacts, both adverse and beneficial, on the species. All such impacts would continue under the No Action Alternative, including potential beneficial impacts of elevated water temperatures.
- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for Chinook salmon redds and may create lower flows in October and November. These actions may create elevated water temperatures during these months with a negligible impact on striped bass rearing. These months are outside of their spawning period.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact on striped bass.
- **Fall and Winter Refill and Redd Maintenance:** Under the No Action Alternative Reclamation would continue to maintain fall-run Chinook salmon redds in consideration of rebuilding storage and coldwater pool for the subsequent year. Impacts of these actions on striped bass are expected to be negligible as flows are likely adequate even when storage volume is low.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on striped bass, as their eggs are free-floating and hatch as they drift downstream, they occur in the lower Sacramento River, and do not appear to be cued by pulsed outflow events.

- **Water Temperature Management:** There may be beneficial impacts of water temperature management in the early summer for egg incubation and rearing through reduction of thermal stress.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH is not expected to impact striped bass.

O.3.12.2 Lower American River

No Action Alternative Components and Striped Bass

- **Seasonal Operations:** Potential adverse and beneficial impacts of reservoir releases on optimal juvenile striped bass rearing conditions would continue under the No Action Alternative.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact as striped bass appear to be less susceptible to stranding in the lower American River.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit rearing striped bass.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on striped bass, as spawning is not well documented in the lower American River, their eggs are free-floating and negatively buoyant and hatch as they drift downstream, and do not appear to be cued by pulsed outflow events.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and are expected to have a negligible impact, as striped bass eggs are free-floating and hatch as they drift downstream, and spawning in the lower American River is not well documented.
- **Water Temperature Management:** Under the No Action Alternative, there may be beneficial impacts of continued water temperature management for juveniles rearing through reduction of thermal stress May through October.

O.3.12.3 Stanislaus River

No Action Alternative Components and Striped Bass

- **Seasonal Operations:** Potential adverse and beneficial impacts of reservoir releases on optimal striped bass spawning and rearing conditions would continue under the No Action Alternative.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact as striped bass appear to be less susceptible to stranding in the lower Stanislaus River.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning and rearing striped bass.

- **Winter Instability Flows:** Winter instability flows are intended to simulate a natural hydrograph to benefit salmonids and are expected to have a negligible impact on striped bass, as these months are outside their spawning period and striped bass do not appear to be cued by winter outflow events.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on striped bass, as their eggs are free-floating and hatch as they drift downstream, and do not appear to be cued by pulsed outflow events.
- **Fall Pulse Flows:** Fall pulse flows are intended help salmonid migration and are expected to have a negligible impact on striped bass, as these months are outside their spawning period and striped bass do not appear to be cued by fall outflow events.

O.3.12.4 Bay-Delta

No Action Alternative Components and Striped Bass

- **Seasonal Operations:** Seasonal operations of OMR management season may cause adverse or beneficial impacts for striped bass in the Delta dependent on fish presence, distribution, and flows.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. Striped bass may benefit from increased flow velocities in Delta channels during the transfer window. Adverse impacts from entrainment at the south Delta facilities may continue due to the high occurrence of striped bass at the salvage facilities.
- **Agricultural Barriers:** Presence of the barriers may provide a beneficial impact for striped bass as shown by increased predation opportunities during operation of the West False River temporary barrier (ICF-ESA Joint Venture 2022).
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative is expected to have an adverse impact on striped bass due to the presence of juveniles during the July 1 to August 31 treatment period and their sensitivity to copper based herbicides (Bills et al. 1993).
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the RRDS would occur during the months of September through November. There may be adverse impacts to striped bass through entrainment when the approach velocity temporarily increases but these impacts are minimized through fish screens at the intakes.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.

- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to striped bass from the Tracy and Skinner fish facilities would occur, including mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on striped bass would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to striped bass resulting from reduced entrainment risk would be unchanged.
- **Spring Delta Outflow:** With year-round presence, impacts of spring delta outflow on striped bass are uncertain. Increased outflow may expedite the rate at which their prey base migrates through the system and could diminish their ability to access that prey.
- **Barker Slough Pumping Plant:** No impacts on striped bass from BSPP operations are anticipated.
- **Delta Smelt Supplementation:** Under the No Action Alternative, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with a negligible impact on striped bass through prey availability. In a recent gut content analysis by Stompe et al. 2020, Delta smelt were not the predominant prey item for striped bass. There have been indications of Delta smelt predation in historical data, with Delta smelt found in striped bass stomach contents collected before the drastic decline of the species (Thomas 1967).
- **Delta Smelt Summer and Fall Habitat:** With year-round presence, impacts of the summer and fall habitat action on striped bass are uncertain. Increased outflow may expedite the rate at which their prey base migrates through the system and could diminish their ability to access that prey.

O.3.13 American Shad

O.3.13.1 Sacramento River

No Action Alternative Components and American Shad

- **Seasonal Operations:** Given year-round use of the Sacramento River by multiple life-stages of American shad, impacts of seasonal operations of Shasta Reservoir and other common components have numerous impacts, both adverse and beneficial, on the species. All such impacts would continue under the No Action Alternative.
- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for Chinook salmon redds and may create lower flows in October and November. These actions may create elevated water temperatures during these months with a negligible impact on American shad. These months are outside of their spawning period.

- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact, as American shad appear to be less susceptible to stranding in the Sacramento River.
- **Fall and Winter Refill and Redd Maintenance:** Impacts on American shad are expected to be negligible, as flows are likely adequate even when storage volume is low.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on American shad, as the window is outside the juvenile rearing and emigration period, and adults do not appear to be cued by pulsed outflow events.
- **Water Temperature Management:** American shad tolerate a wide range of temperatures for spawning and larval rearing. Water temperature management is expected to have a negligible impact on American shad.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH is expected to have a negligible direct impact on American shad.

O.3.13.2 Lower American River

No Action Alternative Components and American Shad

The No Action Alternative consists of components common to all other Alternatives ("common components") and components unique to the No Action Alternative. Discussed here are all components that occur in the lower American River and how operations of those components under the No Action Alternative may impact American shad present in the system.

- **Seasonal Operations:** Potential adverse and/or beneficial impacts on American shad would continue under the No Action Alternative, and include the potential for juvenile stranding.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact on American shad, as adults do not appear to be cued by pulsed outflow events.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit rearing American shad.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on American shad, as the window is outside the juvenile rearing and emigration period, and adults do not appear to be cued by pulsed outflow events.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and are expected to have a negligible impact on American shad, as American shad appear to be less susceptible to stranding in the lower American River.

- **Water Temperature Management:** Under the No Action Alternative, there are expected negligible impacts of continued water temperature management for American shad. American shad tolerate a wide range of temperatures for spawning and larval rearing.

O.3.13.3 Stanislaus River

No Action Alternative Components and American Shad

The No Action Alternative consists of components common to all other Alternatives ("common components") and components unique to the No Action Alternative. Discussed here are all components that occur in The Stanislaus River and how operations of those components under the No Action Alternative may impact American shad present in the system.

- **Seasonal Operations:** Reclamation seeks to minimize potential redd dewatering, redd scouring, and stranding for salmonids. Potential adverse and beneficial impacts from water temperatures outside the optimal range for American shad spawning and rearing conditions would continue under the No Action Alternative.
- **Ramping Rates:** Reclamation will coordinate releases on the Stanislaus River based on prescribed ramping rates and depending on water year type. Current ramping rate conditions are likely to continue to have a negligible impact on American shad.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit spawning and rearing American shad.
- **Winter Instability Flows:** Winter instability flows would continue under the No Action Alternative, and would likely have a negligible impact on American shad, as these months are outside their spawning period and American shad do not appear to be cued by winter outflow events.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on American shad, as the window is outside the juvenile rearing and emigration period, and adults do not appear to be cued by pulsed outflow events.
- **Fall Pulse Flows:** Fall pulse flows are intended help salmonid migration and are expected to have a negligible impact on American shad, as these months are outside their spawning period and American shad do not appear to be cued by fall outflow events.

O.3.13.4 Bay-Delta

No Action Alternative Components and American Shad

The No Action Alternative consists of components common to all other Alternatives ("common components") and components unique to the No Action Alternative. Discussed here are all components that occur in the Bay-Delta and how operations of those components under the No Action Alternative may impact American shad present in the system.

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on American shad include

south Delta entrainment and reduced velocities within some migratory corridors. This would include operations of Old and Middle River Reverse Flow Management (OMR management) season. Seasonal operations of OMR management season may cause adverse or beneficial impacts for American shad in the Delta dependent on fish presence, distribution, and flows.

- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. American shad may benefit from increased flow velocities in Delta channels during the transfer window. Adverse impacts from entrainment at the south Delta facilities may increase due to the high occurrence of American shad at the salvage facilities.
- **Agricultural Barriers:** DWR would continue to operate three agricultural barriers to maintain water levels for agricultural diversions in parts of the south Delta. Presence of the barriers may adversely impact American shad adult migration in the late spring to the Stanislaus River.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative is expected to have a negligible impact on American shad.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the Roaring River Distribution System (RRDS) would occur during the months of September through November may result in adverse impacts to American shad through entrainment when the approach velocity temporarily increases but these impacts are minimized through fish screens at the intakes.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to American shad from the Tracy and Skinner fish facilities would occur. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on American shad would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to American shad resulting from reduced entrainment risk would continue.
- **Spring Delta Outflow:** With year-round presence, impacts of spring delta outflow on American shad are uncertain. Increased outflow in the spring may provide transport of American shad further seaward, and may it provide increased optimal freshwater habitat.

- **Barker Slough Pumping Plant**: No impacts on American shad from BSPP operations are anticipated, and any occurring would continue under the No Action Alternative.
- **Delta Smelt Supplementation:** Under the No Action, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with no anticipated impact on American shad in the Delta.
- **Delta Smelt Summer and Fall Habitat:** With year-round presence, impacts of the summer and fall habitat action on American shad are uncertain. Increased outflow in the summer and fall may provide transport of American shad further seaward, and may it provide increased optimal freshwater habitat.

O.3.14 Threadfin Shad

O.3.14.1 Sacramento River

No Action Alternative Components and Threadfin Shad

- **Seasonal Operations:** Given year-round use of the Sacramento River by threadfin shad, impacts of seasonal operations of Shasta Reservoir and other common components have numerous impacts, both adverse and beneficial, on the species. All such impacts would continue under the No Action Alternative, including potential beneficial impacts of elevated water temperatures.
- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for winter-run Chinook salmon redds but would likely have a negligible impact on threadfin shad. These months are outside of their spawning period.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact on threadfin shad, as threadfin shad appear to be less susceptible to stranding in the Sacramento Rive.
- **Fall and Winter Refill and Redd Maintenance:** Impacts on threadfin shad are expected to be negligible, as flows are likely adequate even when storage volume is low.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on threadfin shad, as adults do not appear to be cued by pulsed outflow events.
- **Water Temperature Management:** Threadfin shad tolerate a wide range of temperatures for spawning and larval rearing. Water temperature management is expected to have a negligible impact on threadfin shad.
- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH is expected to have a negligible direct impact on threadfin shad because introduction of additional winter-run Chinook salmon in the system is not expected to meaningfully impact other species.

O.3.14.2 Lower American River

No Action Alternative Components and Threadfin Shad

- **Seasonal Operations:** Potential impacts on threadfin shad would continue under the No Action Alternative, including the potential for juvenile stranding.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact on threadfin shad, as threadfin shad appear to be less susceptible to stranding in the lower American River.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and could benefit rearing threadfin shad.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on threadfin shad, as adults do not appear to be cued by pulsed outflow events.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and are expected to have a negligible impact on threadfin shad, as threadfin shad appear to be less susceptible to stranding in the lower American River.
- **Water Temperature Management:** Under the No Action Alternative, there are expected negligible impacts of continued water temperature management for threadfin shad. Threadfin shad tolerate a wide range of temperatures for spawning and larval rearing.

O.3.14.3 Stanislaus River

No Action Alternative Components and Threadfin Shad

- **Seasonal Operations:** Reclamation seeks to minimize potential redd dewatering, redd scouring, and stranding for salmonids. Potential adverse and beneficial impacts from water temperatures outside the optimal range for threadfin shad spawning and rearing conditions would continue under the No Action Alternative.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact on threadfin shad.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and are expected to have a negligible impact on threadfin shad, as flows are likely adequate for spawning and juvenile rearing.
- **Winter Instability Flows:** Winter instability flows are intended to simulate a natural hydrograph to benefit salmonids and are expected to have a negligible impact on threadfin shad, as these months are outside their spawning period and threadfin shad do not appear to be cued by winter outflow events.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on threadfin shad, as adults do not appear to be cued by pulsed outflow events.

- **Fall Pulse Flows:** Fall pulse flows are intended help salmonid migration and are expected to have a negligible impact on threadfin shad, as these months are outside their spawning period and threadfin shad do not appear to be cued by fall outflow events

O.3.14.4 Bay-Delta

No Action Alternative Components and Threadfin Shad

- **Seasonal Operations:** Seasonal operations of OMR management season may cause adverse or beneficial impacts for threadfin shad in the Delta dependent on fish presence, distribution, and flows.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. threadfin shad may benefit from increased flow velocities in Delta channels during the transfer window. Adverse impacts from entrainment at the south Delta facilities may continue due to the high occurrence of threadfin shad at the salvage facilities.
- **Agricultural Barriers:** Presence of the barriers are expected to have a negligible impact on threadfin shad, as the barriers are not expected to impede migration.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative is expected to have an adverse impact on threadfin shad, as non-native submerged aquatic vegetation provides important habitat for spawning and larval rearing (Grimaldo et al. 2004).
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for RRDS may result in adverse impacts to threadfin shad through entrainment when the approach velocity temporarily increases but these impacts are minimized through fish screens at the intakes.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to threadfin shad from the Tracy and Skinner fish facilities would occur, including mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on threadfin shad would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to threadfin shad resulting from reduced entrainment risk would be unchanged.

- **Spring Delta Outflow:** With year-round presence, impacts of spring delta outflow on threadfin shad are uncertain. Increased outflow in the spring may provide transport of threadfin shad further seaward, and may it provide increased optimal freshwater habitat.
- **Barker Slough Pumping Plant:** No impacts on threadfin shad from BSPP operations are anticipated, and any occurring would continue under the No Action Alternative.
- **Delta Smelt Supplementation:** Under the No Action, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with no anticipated impact on threadfin shad in the Delta.
- **Delta Smelt Summer and Fall Habitat:** With year-round presence, impacts of the summer and fall habitat action on threadfin shad are uncertain. Increased outflow in the summer and fall may provide transport of threadfin shad further seaward, and may it provide increased optimal freshwater habitat.

O.3.15 Black Basses

O.3.15.1 Sacramento River

No Action Alternative Components and Black Basses

- **Seasonal Operations:** Given year-round use of the Sacramento River by multiple life-stages of black basses, impacts of seasonal operations of Shasta Reservoir and other common components have numerous impacts, both adverse and beneficial, on the species.
- **Rice Decomposition Smoothing:** The delivery schedule considers dewatering risk for Chinook salmon redds and may create lower flows in October and November. These actions may create elevated water temperatures during these months with a negligible impact on black bass spawning. These months are outside of their spawning period.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impacts on black basses, as these species appear to be less susceptible to stranding in the Sacramento River.
- **Fall and Winter Refill and Redd Maintenance:** Under the No Action Alternative Reclamation would continue to maintain fall-run Chinook salmon redds in consideration of rebuilding storage and coldwater pool for the subsequent year. Impacts of these actions on black basses are expected to be negligible as flows are likely adequate even when storage volume is low.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on black basses, as adults do not appear to be cued by pulsed outflow events.
- **Water Temperature Management:** There may be adverse impacts of water temperature management on largemouth bass and spotted bass, as non-spawning adults prefer warmer water temperatures (Moyle 2002; Wang et al. 2010). Impacts are expected to be negligible for smallmouth bass, as they prefer cooler range of water temperatures (Moyle 2002).

- **Winter-Run Chinook Salmon Supplementation:** Under the No Action Alternative, increased use of Livingston-Stone NFH is not expected to impact black basses.

O.3.15.2 Lower American River

No Action Alternative Components and Black Basses

- **Seasonal Operations:** Potential impacts on black basses would continue under the No Action Alternative, and include the potential for adverse impacts of colder water temperatures on largemouth bass and spotted bass and beneficial impacts of higher flows on spawning and rearing habitat for all black basses.
- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact on black basses, as these species appear to be less susceptible to stranding in the Sacramento River.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and may decrease water temperatures when flows are released from Folsom Reservoir. There may be adverse impacts of decreases in water temperature on largemouth bass and spotted bass, as non-spawning adults prefer warmer water temperatures (Moyle 2002; Wang et al. 2010). Impacts are expected to be negligible for smallmouth bass, as they prefer cooler range of water temperatures (Moyle 2002).
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on black basses, as adults do not appear to be cued by pulsed outflow events.
- **Redd Dewatering Adjustments:** Redd dewatering adjustments would continue under the No Action Alternative and are expected to have a negligible impact on black basses, as black bass eggs are typically not at risk of dewatering.
- **Water Temperature Management:** There may be adverse impacts of water temperature management on largemouth and spotted bass, as non-spawning adults prefer warmer water temperatures (Moyle 2002; Wang et al. 2010). Impacts are expected to be negligible for smallmouth bass, as they prefer cooler range of water temperatures (Moyle 2002).

O.3.15.3 Stanislaus River

No Action Alternative Components and Black Basses

- **Seasonal Operations:** Reclamation seeks to minimize potential redd dewatering, redd scouring, and stranding for salmonids. Potential adverse and beneficial impacts on black basses through changes in water temperature would continue under the No Action Alternative. In the Stanislaus River, Reclamation operates to a 7.0 milligrams per liter DO requirement at Ripon from June 1 to September 30. This requirement would have a negligible impact on black basses as they are known to tolerate DO levels as low as 1 mg/L (Lee et al. 1980; Moyle 2002).

- **Ramping Rates:** Current ramping rate conditions are likely to continue to have a negligible impact on black basses, as these species appear to be less susceptible to stranding in the Sacramento River.
- **Minimum Instream Flows:** Minimum instream flows would continue under the No Action Alternative and may decrease water temperatures when flows are released from New Melones Reservoir. There may be adverse impacts of decreases in water temperature on largemouth bass and spotted bass, as non-spawning adults prefer warmer water temperatures (Moyle 2002; Wang et al. 2010). Impacts are expected to be negligible for smallmouth bass, as they prefer cooler range of water temperatures (Moyle 2002).
- **Winter Instability Flows:** Winter instability flows are intended to simulate a natural hydrograph to benefit salmonids and are expected to have a negligible impact on black basses, as these months are outside their spawning period and black basses do not appear to be cued by winter outflow events.
- **Spring Pulse Flows:** Spring pulse flows are intended help salmonid migration and are expected to have a negligible impact on black basses, as adults do not appear to be cued by pulsed outflow events.
- **Fall Pulse Flows:** Fall pulse flows are intended help salmonid migration and are expected to have a negligible impact on black basses, as these months are outside their spawning period and black basses do not appear to be cued by fall outflow events.

O.3.15.4 Bay-Delta

No Action Alternative Components and Black Basses

- **Seasonal Operations:** Seasonal operations of OMR management season may cause adverse or beneficial impacts for black basses in the Delta dependent on fish presence, distribution, and flows.
- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. Adverse impacts from entrainment at the south Delta facilities may increase, particularly for largemouth bass due to their high occurrence at the salvage facilities.
- **Agricultural Barriers:** DWR would continue to operate three agricultural barriers to maintain water levels for agricultural diversions in parts of the south Delta. Presence of the barriers may provide a beneficial impact for black basses, as increased predation opportunities have been observed at the West False River temporary barrier (ICF-ESA Joint Venture 2022).
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative is expected to have an adverse impact on largemouth bass through removal of habitat and cover for predatory behaviors. Impacts on smallmouth bass and spotted bass are likely negligible, as they are not closely associated with aquatic weeds for their predatory behaviors.

- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the Roaring River Distribution System (RRDS) would occur during the months of September through November. There may be limited impacts to black basses through entrainment.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to black basses from the Tracy and Skinner fish facilities would occur, including mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on black basses would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to black basses resulting from reduced entrainment risk would continue.
- **Spring Delta Outflow:** With year-round presence, impacts of spring delta outflow on black basses are uncertain. Increased outflow may expedite the rate at which their prey base migrates through the system and could diminish their ability to access that prey.
- **Barker Slough Pumping Plant:** No impacts on black basses from BSPP operations are anticipated.
- **Delta Smelt Supplementation:** Under the No Action, Reclamation proposes to continue supplementation of Delta smelt through hatchery propagation with negligible impacts on black basses through prey availability. In predator-prey interaction studies, Delta smelt were not the predominant prey item for largemouth or smallmouth bass (Grossman et al. 2016; Weinersmith et al. 2019).
- **Delta Smelt Summer and Fall Habitat:** With year-round presence, impacts of the summer and fall habitat action on black basses are uncertain. Increased outflow may expedite the rate at which their prey base migrates through the system and could diminish their ability to access that prey.

O.3.16 Starry Flounder

O.3.16.1 Bay-Delta

No Action Alternative Components and Starry Flounder

- **Seasonal Operations:** Seasonal operations of OMR management season may cause adverse and/or beneficial impacts for starry flounder in the Delta dependent on fish presence, distribution, and flows.

- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. It is uncertain if increased flow velocities in Delta channels during the transfer window have impacts on starry flounder. Entrainment of starry flounder at the south Delta facilities may increase but impacts are expected to be minimal due to their limited abundance in the south Delta.
- **Agricultural Barriers:** Few starry flounder would be expected to occur in the region of the agricultural barriers during the period when the barriers are present. Under the No Action Alternative, impacts to starry flounder would be minimal.
- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative is expected to have a negligible impact on starry flounder; young of year starry flounder shift to rearing in higher salinity habitats (10-15 ppt) by July through August (Baxter 1999) which is during the July 1 to August 31 treatment period.
- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the RRDS would occur during the months of September through November. There may be potential adverse impacts to starry flounder such as entrainment.
- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed.
- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to starry flounder from the Tracy and Skinner fish facilities would occur, including mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on starry flounder would be limited by continued management under the No Action Alternative.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to starry flounder resulting from reduced entrainment risk would be unchanged.
- **Spring Delta Outflow:** Increased spring outflow is correlated with increased abundance of starry flounder (Kimmerer 2009, Kimmerer 2002), and any benefits for starry flounder would continue under the No Action Alternative.
- **Barker Slough Pumping Plant:** No impacts on starry flounder from BSPP operations are anticipated.
- **Delta Smelt Supplementation:** No impacts to starry flounder are anticipated under this component of the No Action Alternative.

- **Delta Smelt Summer and Fall Habitat:** Relationships of starry flounder abundance and outflow have been reported for the spring period (Kimmerer et al. 2009), but there is uncertainty in outflow relationships for the summer and fall period. Impacts of increased outflow from the summer and fall habitat action under the No Action Alternative are uncertain.

O.3.17 Coastal Pelagic Species

O.3.17.1 Bay-Delta

No Action Alternative Components and Coastal Pelagic Species

- **Seasonal Operations:** The No Action Alternative would include continuation of current seasonal operations, from which the primary potential impacts on Pacific herring include south Delta entrainment and reduced velocities within some migratory corridors. This would include operations of Old and Middle River Reverse Flow Management (OMR management) season. Seasonal operations of OMR management season may cause adverse and/or beneficial impacts for Northern anchovy and Pacific herring in the Delta dependent on fish presence, distribution, and flows.

- **Water Transfers:** Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July 1 to November 30. It is uncertain if increased flow velocities in Delta channels during the transfer window have beneficial impacts on Pacific herring. Pacific herring occurrence in salvage is rare, and impacts may be potentially adverse in drier water year types through increased entrainment. There are no expected impacts to Northern anchovy from water transfers since their distribution is limited to the San Francisco Estuary.

- **Agricultural Barriers:** The barriers are likely to have a negligible impact on Pacific herring. There are no expected impacts to Northern anchovy from agricultural barriers since their distribution is limited to the San Francisco Estuary.

- **Clifton Court Forebay Weed Management:** Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative is expected to have a negligible impact on Pacific herring since age-0 fish typically begin migration to higher salinity waters during the early summer which is outside of the July 1 to August 31 treatment period. There are no expected impacts to Northern anchovy from Clifton Court Forebay weed management since their distribution is limited to the San Francisco Estuary.

- **Suisun Marsh Roaring River Distribution System Fall Flood-Up:** Under the No Action Alternative, the 5-week annual flood-up window for the RRDS would occur during the months of September through November. There may be potential adverse impacts to Pacific herring and Northern anchovy such as entrainment.

- **Delta Cross Channel Gates:** Operation of the DCC and resulting probabilities of entrainment would continue under the No Action Alternative: fish migrating past the gates could be entrained when they are open or blocked from entering the interior Delta when they are closed. It is uncertain whether this could impact Pacific herring that

occasionally occur in the Delta during drier water year types. There are no expected impacts to Northern anchovy from the DCC gates since their distribution is limited to the San Francisco Estuary.

- **Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility:** Under the No Action Alternative, potential impacts to Pacific herring from the Tracy and Skinner fish facilities would occur including mortality from pre-screen loss, collection, handling, transport, and release. The potential impacts from the Tracy and Skinner fish salvage facilities on Pacific herring would be limited by continued management under the No Action Alternative. There are no expected impacts to Northern anchovy since their distribution is limited to the San Francisco Estuary.
- **Seasonal and Real-Time Management of Old and Middle River Reverse Flow:** All components of OMR management would continue under the No Action Alternative, and beneficial impacts to Pacific herring resulting from reduced entrainment risk would be unchanged. There are no expected impacts to Northern anchovy since their distribution is limited to the San Francisco Estuary.
- **Spring Delta Outflow:** Spring Delta Outflow may have negligible impacts on coastal pelagic species. The distribution of Northern anchovy in the San Francisco Estuary has shifted towards higher salinities (> 20) since the introduction of the invasive clam, *Potamocorbula amurensis* (Kimmerer 2006); therefore, Spring Delta Outflow is expected to have no impact on the Northern anchovy. Kimmerer (2009) found Pacific herring abundance was not significantly associated with spring outflow.
- **Barker Slough Pumping Plant:** There are no expected impacts to Northern anchovy since their distribution is limited to the San Francisco Estuary.
- **Delta Smelt Supplementation:** No impacts to coastal pelagic species are anticipated under this component of the No Action Alternative.
- **Delta Smelt Summer and Fall Habitat:** The summer and fall habitat action may have negligible impacts on coastal pelagic species. The distribution of Northern anchovy in the San Francisco Estuary has shifted towards higher salinities (> 20) since the introduction of the invasive clam, *Potamocorbula amurensis* (Kimmerer 2006); therefore, there is no expected impact on the Northern anchovy. Pacific herring move into higher salinity waters into the summer as they grow therefore Summer and Fall habitat may have a negligible impact.

O.3.18 Southern Oregon/Northern California Coast Coho Salmon ESU

O.3.18.1 Trinity River

Habitat conditions for coho salmon in the Trinity River are expected to continue to improve under the No Action Alternative. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish, including coho salmon. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that support habitat-forming processes, maintain suitable water temperatures, and support life-stage-specific habitat requirements. In addition, peak flow releases are expected to interact with existing and new habitat restoration actions to promote continuing geomorphic change to increase habitat complexity and spatial and temporal stream temperature diversity. Habitat improvements and seasonal flow releases under the No Action Alternative are expected to maintain a low risk of disease outbreaks for coho salmon, although there is uncertainty in how disease prevalence will affect future disease risk for coho salmon.

Under the No Action Alternative, the synergistic impact of variable annual flows interacting with the channel's morphological conditions and planned restoration actions is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for coho salmon under the No Action Alternative.

Potential Changes to Coho Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations

Seasonal operations in the Trinity River are expected to maintain suitable habitat conditions for coho salmon spawning and egg/alevin incubation under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below (downstream of) Lewiston Dam would continue to be managed to maintain suitable habitat conditions for anadromous fish. The variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel and is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment. Modeled monthly average flows would be equal to or greater than 300 cfs in all water year types to provide suitable water depth and velocity for coho salmon throughout the spawning period, including November and December when the majority of spawning occurs. Average flows from November through early May when most coho salmon egg/alevin incubation occurs would likewise be equal to or greater than 300 cfs in all water year types, and substantially greater in the wettest water years in some months, to provide suitable conditions for incubation and emergence.

Modeled monthly average flow in November and December would maintain modeled monthly average and monthly maximum water temperatures in the Trinity River below Lewiston Dam cooler than the upper water temperature objective of 56°F to protect spawning coho salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11; temperatures see Appendix F, Figure F.2.11-1-1). Although the 56°F objective is intended to be measured at the North Fork Trinity River confluence 40 river miles (RM) downstream of Lewiston Dam and refers to a daily average temperature, historical data and model results suggest that water temperatures in this reach of the Trinity River during November and December, as well as January through mid-May, would generally remain well below the 56°F objective under a wide

range of flow scenarios (Asarian et al. 2023) and temperatures under the No Action Alternative would remain suitable for spawning and incubating coho salmon.

Table O-11. Water Temperature Objectives for the 40-Mile Reach from Lewiston Dam Downstream to the Confluence with the North Fork Trinity River

Location	Date	Daily Average Temperature Not to Exceed
Douglas City (RM 93.8)	July 1 through September 14	60°F
Douglas City (RM 93.8)	September 15 through September 30	56°F
North Fork Trinity River (RM 72.4)	October 1 through December 31	56°F

Source: NCRWQCB 2018: 3–13.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions for coho salmon spawning and egg/alevin incubation in the Trinity River. Under current conditions, substantial changes in the availability or suitability of coho salmon spawning and egg/alevin incubation habitat are unlikely and no adverse impacts on coho salmon are expected.

Potential Changes to Coho Salmon Juvenile Rearing and Emigration from Seasonal Operations

Seasonal operations in the Trinity River are generally expected to maintain suitable habitat conditions for coho salmon rearing and emigration under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. The flow regime included in the Trinity River ROD (USDOI 2000) is intended to provide juvenile coho salmon access to a diversity of habitats throughout the year as they grow. Modeled monthly average flows would be equal to or greater than 300 cfs in all water year types to provide a range of suitable depth and velocity, access to cover, and other physical habitat elements to support rearing coho salmon throughout the year. Average flows from January to mid-summer when yearling coho salmon emigrate to the ocean would likewise be equal to or greater than 300 cfs in all water year types, and substantially greater in some months and water years, to provide depths and velocities suitable for downstream movement and water temperatures suitable for smoltification. Relatively high flows in the spring are intended to mimic the natural snowmelt runoff hydrograph and provide access to low-velocity floodplain habitat for coho salmon fry and early juvenile rearing and to promote juvenile (smolt) outmigration.

Modeled monthly average flow under the No Action Alternative would generally maintain modeled monthly average water temperatures in the Trinity River below Lewiston Dam cooler than the recommended 59°F water temperature objective for emigrating juvenile coho salmon for normal and wetter water year types and 62.6°F for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures from January through May would typically remain below the

59°F objective in above normal and wet water years and below the 62.6°F objective in dry and critically dry water years at most locations downstream to Weitchpec (Asarian et al. 2023). The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under the No Action Alternative through July at Douglas City but would not be met at the North Fork Trinity River confluence in June of drier water year types or in July of all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the coho salmon juvenile rearing and emigration period at downstream locations in some water year types under the No Action Alternative, water temperatures and the potential impacts on coho salmon would not differ from current conditions.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions in most months and water year types for coho salmon juvenile rearing and emigration in the Trinity River.

Potential Changes to Coho Salmon Adult Upstream Migration and Holding from Seasonal Operations

Seasonal operations in the Trinity River are expected to maintain suitable habitat conditions for coho salmon upstream migration and holding under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish including coho salmon. Modeled monthly average flows from August to January when adult coho salmon are migrating and holding would be equal to or greater than 300 cfs in all water year types to provide suitable depth for upstream passage, access to cover, and holding habitat to support pre-spawning coho salmon. Monthly average flows in August and September, when adult coho salmon begin migrating upstream from the ocean and water temperatures may be at or near seasonal highs (Asarian et al. 2023), would be equal to or greater than 760 cfs in all water year types to maintain suitable water temperatures for adult upstream migration (60°F in August and early September and 56°F in late September; Table O-11). Historical data and model results suggest that water temperatures in August and September would typically remain below the objectives at Douglas City (Asarian et al. 2023) and temperatures under the No Action Alternative would be generally suitable for coho salmon upstream migration and holding. During the late September to mid-November peak adult migration period, the monthly average flows in most water year types would likely maintain suitable water temperatures for migration. Seasonal flow releases under the No Action Alternative are also expected to maintain a relatively low risk of disease outbreaks for coho salmon by maintaining minimum flows and relatively cool water temperatures. Despite the potential for exceedance of some water temperature objectives in portions of the coho salmon upstream migration and holding period under the No Action Alternative, water temperatures and the potential impacts on coho salmon would not differ from current conditions.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions in most months and water year types for coho salmon upstream migration and holding in the Trinity River. Under the No Action Alternative, substantial changes in the availability or suitability of coho salmon adult migration and holding habitat would be minimal, and no adverse impacts on coho salmon are expected.

O.3.19 Upper Klamath-Trinity River Spring-Run Chinook Salmon ESU

O.3.19.1 Trinity River

Habitat conditions for spring-run Chinook salmon in the Trinity River are expected to continue to improve under the No Action Alternative. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to maintain suitable habitat conditions for anadromous fish, including Chinook salmon. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that support habitat-forming processes, maintain suitable water temperatures, and support life-stage-specific habitat requirements. In addition, peak flow releases are expected to interact with existing and new habitat restoration actions to promote continuing geomorphic change to increase habitat complexity and spatial and temporal stream temperature diversity. Habitat improvements and seasonal flow releases under the No Action Alternative would be expected to maintain a low risk of disease outbreaks for spring-run Chinook salmon, although there is uncertainty in how disease prevalence will affect future disease risk for spring-run Chinook salmon.

Under the No Action Alternative, the synergistic impact of variable annual flows interacting with the channel's morphological conditions and planned restoration actions is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for spring-run Chinook salmon under the No Action Alternative.

Potential Changes to Spring-run Chinook Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations

Under the No Action Alternative, seasonal operations in the Trinity River are expected to maintain suitable habitat conditions for spring-run Chinook salmon spawning and egg/alevin incubation. Modeled monthly average flows below (downstream of) Lewiston Dam would be equal to or greater than 300 cfs in all water year types to provide suitable habitat conditions for spring-run Chinook salmon throughout the spawning period, including monthly average flows of 373 cfs in October when the majority of spawning occurs. Average flows from September through February when most spring-run Chinook salmon egg/alevin incubation occurs would likewise be equal to or greater than 300 cfs in all water year types, and substantially greater in the wettest water years in some months, to provide suitable conditions for incubation and emergence. The variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

Modeled monthly average flow in September–November would maintain modeled monthly average and monthly maximum water temperatures in the Trinity River below Lewiston Dam cooler than the upper water temperature objective of 56°F to protect spawning spring-run Chinook salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11). Although the 56°F objective is intended to be measured at the North Fork Trinity River confluence 40 river miles (RM) downstream of Lewiston Dam and refers to a daily average temperature, historical data and model results suggest that water temperatures in this reach of the Trinity River from October through February would generally remain below the 56°F objective in all water year types (Asarian et al. 2023) and water temperatures under the No Action Alternative would be suitable for spawning spring-run Chinook salmon during the majority of

the spawning and incubation period. However, water temperatures in September may exceed the 56°F objective at locations downstream of Douglas City (RM 93.8, approximately 21 river miles upstream of North Fork Trinity River), especially in drier water year types (Asarian et al. 2023). Similarly, water temperatures recommended by TRRP scientists to support salmon incubation may be exceeded during the driest water years. In water year 2022, a critically dry year, the recommended objectives at Lewiston of < 53.4°F September 15–October 31 and < 50°F November–February were exceeded in 28% of the target period (Buxton 2023). During the 100-year simulation period used for the CalSim3 modeling included in this EIS, critically dry water years occurred 16% of the time. Despite the potential for exceedance of some water temperature objectives in portions of the spring-run Chinook salmon spawning and incubation period in some water year types under the No Action Alternative, water temperatures and the potential impacts on spring-run Chinook salmon would not differ from current conditions.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions for spring-run Chinook salmon spawning and egg/alevin incubation in the Trinity River in most months and water year types. U

Potential Changes to Spring-run Chinook Salmon Juvenile Rearing and Emigration from Seasonal Operations

Seasonal operations in the Trinity River are generally expected to maintain suitable habitat conditions for spring-run Chinook salmon rearing and emigration under the No Action Alternative. Under the No Action Alternative, the flow regime included in the Trinity River ROD (USDOI 2000) is intended to provide spring-run Chinook salmon access to a diversity of habitats throughout the year as they grow. Monthly average flows would be greater than or equal to 300 cfs in all water year types to provide a range of suitable depth and velocity, access to cover, and other habitat elements to support rearing spring-run Chinook salmon. Average flows from winter through mid-summer when spring-run Chinook salmon emigrate to the ocean would likewise be greater than or equal to 300 cfs in all water year types, and substantially greater in April–July in all water year types, to provide conditions suitable for downstream movement and water temperatures suitable for smoltification. Relatively high flows in the spring are intended to mimic the natural snowmelt runoff hydrograph and provide access to low-velocity floodplain habitat for spring-run Chinook salmon fry and early juvenile rearing and to promote juvenile (smolt) outmigration.

Modeled monthly average flows under the No Action Alternative would generally maintain modeled monthly average water temperatures in the Trinity River below Lewiston Dam cooler than the recommended 62.6°F water temperature objective for emigrating juvenile spring-run Chinook salmon for Normal and wetter water year types and 68°F for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that daily average water temperatures under the No Action Alternative would typically remain below the 62.6°F objective for Normal and wetter water year types in all reaches of the Trinity River through June and upstream of the North Fork Trinity River confluence in July (Asarian et al. 2023). Historical data and model results suggest that daily average water temperatures under the No Action Alternative would typically remain below the 68°F objective for dry and critically dry water year types in all reaches through May and downstream at least to the North Fork Trinity River through July (Asarian et al. 2023). The

61.7°F water temperature objective recommended by TRRP scientists to support salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under the No Action Alternative through July at Douglas City but would not be met at the North Fork Trinity River confluence in June of drier water year types or in July of all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the spring-run Chinook salmon juvenile rearing and emigration period at downstream locations in some water year types under the No Action Alternative, water temperatures and the potential impacts on spring-run Chinook salmon would not differ from current conditions.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions in all but the warmest summer months and the driest water year types for spring-run Chinook salmon juvenile rearing and emigration in the Trinity River..

Potential Changes to Spring-run Chinook Salmon Adult Upstream Migration and Holding from Seasonal Operations

Seasonal operations in the Trinity River are expected to maintain suitable habitat conditions for spring-run Chinook salmon upstream migration and holding under the No Action Alternative . Under the No Action Alternative, modeled monthly average flows from April through September when adult spring-run Chinook salmon are migrating and holding would be equal to or greater than 500 cfs in nearly all water year types to provide a range of suitable depth for upstream passage, access to cover, and holding habitat to support pre-spawning spring-run Chinook salmon. Modeled monthly average flows in July–September, when adult spring-run Chinook salmon are migrating and holding and water temperatures may be at or near seasonal highs (Asarian et al. 2023), would be near or greater than 500 cfs in all water year types and substantially higher in some months and water year types to maintain suitable water temperatures for adults (60°F from July 1-September 14 at Douglas City and 56°F from September 15-30 at Douglas City). Although historical data and model results suggest that water temperatures throughout these periods would typically remain below the objectives at Douglas City (Asarian et al. 2023), data from water year 2022, a critically dry year, show that the Douglas City objectives were not met for 72% of the target period (Buxton 2023). During the 100-year simulation period used for the CalSim3 modeling included in this EIS, critically dry water years occurred 16% of the time. Despite the potential for exceedance of the adult spring-run Chinook salmon water temperature objectives in portions of the upstream migration and holding period in the driest water year types under the No Action Alternative, water temperatures and the potential impacts on spring-run Chinook salmon would not differ from current conditions.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions in most months and water year types for spring-run Chinook salmon upstream migration and holding in the Trinity River.

O.3.20 Upper Klamath-Trinity River Fall-Run Chinook Salmon ESU

O.3.20.1 Trinity River

Habitat conditions for fall-run Chinook salmon in the Trinity River are expected to continue to improve under the No Action Alternative. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that support habitat-forming processes, maintain suitable water temperatures, and provide access to life-stage-specific habitat attributes. In addition, peak flow releases are expected to interact with existing and new restoration actions to promote continuing geomorphic change to increase habitat complexity and the spatial and temporal diversity of stream temperatures. Habitat improvements and seasonal flow releases would be expected to reduce the threat of disease outbreaks for fall-run Chinook salmon, although there is uncertainty in how disease prevalence will affect future disease risk for fall-run Chinook salmon.

Under the No Action Alternative, the synergistic impact of variable annual flows interacting with the channel's morphological conditions and planned restoration actions is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for fall-run Chinook salmon under the No Action Alternative.

Potential Changes to Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations

Under the No Action Alternative, seasonal operations in the Trinity River are expected to maintain suitable habitat conditions for fall-run Chinook salmon spawning and egg/alevin incubation. Modeled monthly average flows below (downstream of) Lewiston Dam would be equal to or greater than 300 cfs in all water year types to provide suitable habitat conditions for fall-run Chinook salmon throughout the spawning period, including modeled monthly average flows of 342 cfs in November when the majority of spawning occurs. Modeled monthly average flows from September through February when most fall-run Chinook salmon egg/alevin incubation occurs would likewise be equal to or greater than 300 cfs in all water year types, and substantially greater in the wettest water years in some months, to provide suitable conditions for incubation and emergence. The variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

Modeled monthly average flow in October–January would maintain modeled monthly average and monthly maximum water temperatures in the Trinity River below Lewiston Dam cooler than the upper water temperature objective of 56°F to protect spawning fall-run Chinook salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11). Although the 56°F objective is intended to be measured at the North Fork Trinity River confluence 40 river miles (RM) downstream of Lewiston Dam and refers to a daily average temperature, historical data and model results suggest that water temperatures in this reach of the Trinity River from October through February would generally remain below the 56°F objective in all water year types (Asarian et al. 2023) and temperatures under the No Action Alternative would be suitable for spawning fall-run Chinook salmon during the majority of the spawning and incubation period.

However, water temperatures recommended by TRRP scientists to support salmon incubation may be exceeded during the driest water years. In water year 2022, a critically dry year, the recommended objectives at Lewiston of < 53.4°F September 15–October 31 and < 50°F November–February were exceeded in 28% of the target period (Buxton 2023). During the 100-year simulation period used for the CalSim3 modeling included in this EIS, critically dry water years occurred 16% of the time. Despite the potential for exceedance of some water temperature objectives in portions of the fall-run Chinook salmon spawning and incubation period in some water year types under the No Action Alternative, water temperatures and the potential impacts on fall-run Chinook salmon would not differ from current conditions.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions for fall-run Chinook salmon spawning and egg/alevin incubation in the Trinity River in most months and water year types.

Potential Changes to Fall-run Chinook Salmon Juvenile Rearing and Emigration from Seasonal Operations

Seasonal operations in the Trinity River are generally expected to maintain suitable habitat conditions for fall-run Chinook salmon juvenile rearing and emigration under the No Action Alternative compared to current conditions. Under the No Action Alternative, the flow regime included in the Trinity River ROD (USDOI 2000) is intended to provide fall-run Chinook salmon access to a diversity of habitats throughout the year as they grow. Monthly average flows would be greater than or equal to 300 cfs in all water year types to provide a range of suitable depth and velocity, access to cover, and other habitat elements to support rearing fall-run Chinook salmon. Average flows from spring through mid-summer when fall-run Chinook salmon emigrate to the ocean would likewise be greater than or equal to 300 cfs in all water year types, and substantially greater in April–July in all water year types, to provide conditions suitable for downstream movement and water temperatures suitable for smoltification. Relatively high flows in the spring are intended to mimic the natural snowmelt runoff hydrograph and provide access to low-velocity floodplain habitat for fall-run Chinook salmon fry and early juvenile rearing and to promote juvenile (smolt) outmigration.

Modeled monthly average flows under the No Action Alternative would generally maintain modeled monthly average water temperatures in the Trinity River below Lewiston Dam cooler than the recommended 62.6°F water temperature objective for emigrating juvenile fall-run Chinook salmon for normal and wetter water year types and 68°F for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that daily average water temperatures under the No Action Alternative would typically remain below the 62.6°F objective for normal and wetter water year types in all reaches of the Trinity River through June and upstream of the North Fork Trinity River confluence in July (Asarian et al. 2023). Historical data and model results suggest that daily average water temperatures under the No Action Alternative would typically remain below the 68°F objective for dry and critically dry water year types in all reaches through May and downstream at least to the North Fork Trinity River through July (Asarian et al. 2023). The 61.7°F water temperature objective recommended by TRRP scientists to support salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under the No Action Alternative through July at Douglas City but would not be met at the North Fork

Trinity River confluence in June of drier water year types or in July of all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the fall-run Chinook salmon juvenile rearing and emigration period at downstream locations in some water year types under the No Action Alternative, water temperatures and the potential impacts on fall-run Chinook salmon would not differ from current conditions.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions in all but the warmest summer months and the driest water year types for fall-run Chinook salmon juvenile rearing and emigration in the Trinity River.

Potential Changes to Fall-run Chinook Salmon Adult Upstream Migration and Holding from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for fall-run Chinook salmon upstream migration and holding under the No Action Alternative.. Under the No Action Alternative, modeled monthly average flows from August through November when adult fall-run Chinook salmon are migrating and preparing to spawn would be equal to or greater than 300 cfs in nearly all water year types to provide a range of suitable depth for upstream passage, access to cover, and holding habitat to support pre-spawning fall-run Chinook salmon. Modeled monthly average flows in September through November, when adult fall-run Chinook salmon are migrating and preparing to spawn and water temperatures near seasonal highs (Asarian et al. 2023), would be near or greater than 300 cfs in all water year types and substantially higher in some months and water year types to maintain suitable water temperatures for adults (60°F from July 1–September 14 at Douglas City and 56°F from September 15–30 at Douglas City). Although historical data and model results suggest that water temperatures throughout these periods would typically remain below the objectives at Douglas City (Asarian et al. 2023), data from water year 2022, a critically dry year, show that the Douglas City objectives were not met for 72% of the compliance period (Buxton 2023). During the 100-year simulation period used for the CalSim3 modeling included in this EIS, critically dry water years occurred 16% of the time. Despite the potential for exceedance of the adult fall-run Chinook salmon water temperature objectives in portions of the upstream migration and pre-spawning period in the driest water year types under the No Action Alternative, water temperatures and the potential impacts on fall-run Chinook salmon would not differ from current conditions.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions in all but the warmest summer months and the driest water year types for fall-run Chinook salmon adult upstream migration and pre-spawning in the Trinity River.

O.3.21 Klamath Mountains Province Steelhead DPS

O.3.21.1 Trinity River

Habitat conditions for steelhead in the Trinity River are expected to continue improving under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish, including steelhead. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that support

habitat-forming processes, maintain suitable water temperatures, and support life-stage-specific habitat requirements. In addition, peak flow releases are expected to interact with existing and new habitat restoration actions to promote continuing geomorphic change to increase habitat complexity and spatial and temporal stream temperature diversity. Habitat improvements and seasonal flow releases under the No Action Alternative would be expected to maintain a low risk of disease outbreaks for salmonids, including steelhead, although there is uncertainty in how disease prevalence will affect future disease risk for steelhead.

Under the No Action Alternative, the synergistic impact of variable annual flows interacting with the channel's morphological conditions and planned restoration actions is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for steelhead under the No Action Alternative.

Potential Changes to Steelhead Spawning and Egg/Alevin Incubation from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for steelhead spawning and egg/alevin incubation under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below (downstream of) Lewiston Dam would continue to be managed to maintain habitat conditions for anadromous fish. The variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment. Modeled monthly average flows would be equal to or greater than 300 cfs in all water year types and would provide suitable water depth and velocity for steelhead throughout the spawning period (December through May). Average flows from December through June when steelhead egg/alevin incubation can occur would likewise be equal to or greater than 300 cfs in all water year types, and substantially greater in the wettest water years in some months, and would provide suitable conditions for incubation and emergence.

Modeled monthly average flow in December would maintain modeled monthly average and monthly maximum water temperatures in the Trinity River below Lewiston Dam cooler than the upper water temperature objective of 56°F to protect salmonids in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11). Although the 56°F objective is intended to be measured at the North Fork Trinity River confluence 40 river miles (RM) downstream of Lewiston Dam and refers to a daily average temperature, historical data and model results suggest that water temperatures in this reach of the Trinity River in December, as well as January through May, would generally remain well below the 56°F objective under a wide range of flow scenarios (Asarian et al. 2023).

January through May modeled average temperatures immediately downstream of Lewiston Dam would be within the optimal range for incubating eggs (Carter 2005) under the No Action Alternative. Further downstream in the Trinity River, modeled temperatures are suitable and usually optimal for incubating eggs December through May (Asarian 2023) and this would continue under the No Action Alternative. Lethal incubation temperatures in the lower Trinity River mainstem are modeled to occur about half the time in June but incubating eggs and alevins occurring at that location at that time likely make up at most a very small proportion of the total population's eggs in a given year.

Potential Changes to Steelhead Juvenile Rearing and Emigration from Seasonal Operations

Seasonal operations in the Trinity River are generally expected to continue to maintain suitable habitat conditions for steelhead rearing and emigration under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. The flow regime included in the Trinity River ROD (USDOI 2000) is intended to provide juvenile coho salmon access to a diversity of habitats throughout the year as they grow and would also benefit rearing steelhead. Modeled monthly average flows would be equal to or greater than 300 cfs in all water year types to provide a range of suitable depth and velocity, access to cover, and other physical habitat elements to support rearing steelhead throughout the year. Average flows from when steelhead move downstream and some emigrate to the ocean would likewise be equal to or greater than 300 cfs in all water year types, and substantially greater in some months and water years, to provide depths and velocities suitable for downstream movement and water temperatures suitable for smoltification in the lower Trinity River (Asarian et al. 2023). Relatively high flows in the spring are intended to mimic the natural snowmelt runoff hydrograph and provide access to low-velocity floodplain habitat for salmon and steelhead fry and early juvenile rearing and to promote juvenile (smolt) outmigration.

Modeled monthly average flows directly out of Lewiston Reservoir would be below optimal temperatures for rearing and outmigrating juveniles throughout the year but temperatures tend to increase downstream of the dam (Asarian et al. 2023) and juveniles would likely take advantage of acute changes in temperature from diel variations and thermal refugia to optimize rearing and to make their way out of the Trinity River until they reach new rearing habitat in lower Klamath River or they migrate to the ocean. Lethal temperatures for rearing and smoltification are not predicted in the Trinity River downstream of Lewiston Reservoir (Table O-11; Asarian et al. 2023; Richter and Kolmes 2005; McEwan and Jackson 1996; and Moyle 2002). Temperatures under the No Action Alternative would be generally suitable for rearing and emigrating steelhead.

Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions in most months and water year types for steelhead juvenile rearing and emigration in the Trinity River.

Potential Changes to Steelhead Adult Migration and Holding from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for steelhead migration and holding under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish, including steelhead. Modeled monthly average flows would be equal to or greater than 300 cfs in all water year types to provide a range of suitable depth for passage, access to cover, and holding habitat to support adult steelhead. Seasonal flow releases under the No Action Alternative are also expected to reduce the threat of disease outbreaks for steelhead compared to current conditions by maintaining minimum flows and relatively cool water temperatures.

Water temperatures under the No Action Alternative would be generally suitable for steelhead upstream migration and holding. Monthly average flows directly out of Lewiston Reservoir would be below optimal temperatures for migrating and holding adults throughout the year but temperatures tend to increase downstream of the dam (Asarian et al. 2023) and migrating adults or stream-maturing steelhead would likely take advantage of acute water temperature changes in diel variations and thermal refugia to optimize upstream swimming and holding behaviors, until they reach spawning grounds in the Trinity River or its tributaries. Lethal water temperatures for migrating and holding adults are not predicted in the Trinity River downstream of Lewiston Reservoir in month (Table O-11; Asarian et al. 2023; McKenzie et al. 2021; Myrick and Cech 2000; Moyle et al 2015).

Seasonal operations under the No Action Alternative will continue to maintain suitable habitat conditions for steelhead migration and holding in the Trinity River.

O.3.22 Northern DPS Green Sturgeon

O.3.22.1 Trinity River

Green sturgeon distribution in the Trinity River is likely limited to the lower approximately 43 river miles by Grays Falls near Burnt Ranch (Benson et al. 2007). Natural hydrograph elements included in the variable annual flow regime under the No Action Alternative are expected to provide life stage–specific habitat elements that are beneficial to green sturgeon populations.

Potential Changes to Northern DPS Green Sturgeon Spawning and Egg Incubation from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue contributing to the maintenance of suitable habitat conditions for green sturgeon spawning and egg incubation under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from March through July would equal to or greater than 300 cfs in all water year types to provide physical habitat, pools, and suitable temperatures for green sturgeon throughout the spawning and incubation period, including April through June when peak spawning occurs.

Larval and Juvenile Rearing and Emigration

The northern DPS green sturgeon spawning period is from March through July, and the larval period is considered to be March through September. The juvenile stage of green sturgeon begins when metamorphosis of the larva is complete, typically about 45 days after hatching and approximately up to two cm TL. Juveniles (up to 150 cm TL) typically slowly migrate downstream, and rear in the lower Klamath River for up to a year or until approximately their first summer, with optimal growth temperatures ranging from 59–66.2°F (Moyle 2002, Mayfield and Cech 2004). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near Burnt Ranch to the Klamath River Estuary (Section O.1.2.5, *Green Sturgeon, Northern DPS*). The impacts analysis period for larval and juvenile life stages in the Trinity River should be considered April to September.

Potential Changes to Northern DPS Green Sturgeon Larval and Juvenile Rearing and Emigration from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for green sturgeon larval and juvenile rearing and emigration under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows would be at or above 300 cfs in all water year types to provide a range of suitable depths and velocities, and water temperatures to support larval and juvenile rearing. Average flows from summer through fall when juvenile green sturgeon emigrate to the ocean and estuary would likewise be equal to or greater than 300 cfs in all water year types to provide depths and velocities suitable for downstream movement.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Trinity River from the Klamath River Estuary as early as February to make their way upstream to spawn in deep pools from the lower section of the mainstem Trinity River to the confluence with the Klamath River upstream approximately 43 miles to Gray's Falls near Burnt Ranch. After spawning, the adults remain in mainstem river pools for varying amounts of time, representing distinct migration patterns. Directly after spawning, 25% emigrate back to the Klamath River Estuary and ocean, but freshwater residency may last up to 199 days (Moyle 2002; Section O.1.3.2, *Green Sturgeon, Northern DPS*). With the extended adult holding period, impacts analysis of flow and water temperature on adult upstream immigration, holding, and emigration may occur from February through December.

Potential Changes to Northern DPS Green Sturgeon Adult Upstream Migration and Holding from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for green sturgeon upstream migration and holding under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from February to December when adult green sturgeon are immigrating and holding would be equal to or greater than 300 cfs in all water year types to provide a range of suitable depth and velocity for upstream passage and holding pool habitat. During the July to December peak adult emigration period, the monthly average flows would similarly help maintain suitable water depth and velocities for downstream movement.

O.3.23 Eulachon

O.3.23.1 Potential Changes to Eulachon Spawning and Egg Incubation from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue contributing to the maintenance of suitable habitat conditions for eulachon spawning and egg incubation under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from December through June would equal to or greater than 300 cfs in all water year types to provide sufficient flows and suitable temperatures for eulachon throughout the spawning and incubation period, including March and April when peak spawning occurs.

O.3.23.2 Potential Changes to Eulachon Larval Emigration from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for eulachon larval emigration under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from December through June would be at or above 300 cfs in all water year types to provide sufficient flows for downstream movement and suitable temperatures for eulachon throughout the larval emigration period.

O.3.23.3 Potential Changes to Eulachon Adult Upstream Migration from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for eulachon upstream migration under the No Action Alternative. Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from December through May would equal to or greater than 300 cfs in all water year types to provide sufficient flows for upstream migration and suitable temperatures for eulachon throughout the migration period.

O.3.24 Coastal Cutthroat Trout

O.3.24.1 Lower Klamath River from Confluence with Trinity River to Pacific Ocean

Coastal cutthroat trout distribution in the Trinity and Klamath Rivers is limited to tributaries, the mainstem during adult migration and juvenile emigration, and the lower Klamath River estuary. Natural hydrograph elements included in the variable annual flow regime are expected to provide life-stage-specific habitat elements that are beneficial to coastal cutthroat trout populations.

Potential Changes to Coastal Cutthroat Trout Spawning and Egg Incubation from Seasonal Operations

The impacts analysis period for coastal cutthroat trout spawning and egg incubation is September through June. Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for coastal cutthroat trout spawning and egg incubation in the lower Klamath River under the No Action Alternative. Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from September through June would be at or above 300 cfs in all water year types to provide sufficient flows and suitable temperatures for coastal cutthroat trout throughout the spawning and incubation period. Seasonal operations under the No Action Alternative are expected to maintain suitable habitat conditions for coastal cutthroat trout spawning and egg incubation in the lower Klamath River.

Potential Changes to Coastal Cutthroat Trout Juvenile Rearing and Emigration from Seasonal Operations

The impacts analysis period for coastal cutthroat trout juvenile rearing and emigration is April through June for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout. Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for coastal cutthroat trout juvenile rearing and emigration in the lower Klamath River under the No Action Alternative. Trinity River flow and water

temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from April through June would be at or above 300 cfs in all water year types to provide sufficient flows for downstream movement and suitable water temperatures for coastal cutthroat trout throughout the juvenile rearing and emigration period. Seasonal operations under the No Action Alternative are expected to continue to maintain suitable habitat conditions in most months and water year types for coastal cutthroat trout juvenile rearing and emigration in the lower Klamath River.

Potential Changes to Coastal Cutthroat Trout Adult Holding and Migration from Seasonal Operations

The impacts analysis period for coastal cutthroat trout adult holding and migration is August through October for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout. Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for coastal cutthroat trout upstream migration in the lower Klamath River under the No Action Alternative. Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows from January through December would be equal to or greater than 300 cfs in all water year types to provide sufficient flows for upstream migration and suitable temperatures for coastal cutthroat trout throughout the migration period.

Seasonal operations under the No Action Alternative are expected to continue to maintain suitable habitat conditions for coastal cutthroat trout adult holding and migration in the lower Klamath River.

O.3.25 Brown Trout

O.3.25.1 Trinity River

Habitat conditions for brown trout in the Trinity River are expected to continue to improve under the No Action Alternative. Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that support habitat-forming processes, maintain suitable water temperatures, and support life-stage-specific habitat requirements. In addition, peak flow releases are expected to interact with existing and new habitat restoration actions to promote continuing geomorphic change to increase habitat complexity and spatial and temporal stream temperature diversity. Habitat improvements and seasonal flow releases under the No Action Alternative would be expected to maintain a low risk of disease outbreaks for anadromous and potamodromous fish, including brown trout, although there is uncertainty in how disease prevalence will affect future disease risk for brown trout.

Under the No Action Alternative, the synergistic impact of variable annual flows interacting with the channel’s morphological conditions and planned restoration actions is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for brown trout under the No Action Alternative.

Potential Changes to Brown Trout Spawning and Egg Incubation from Seasonal Operations

The impacts analysis period for brown trout spawning and egg incubation is November through April. Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for brown trout spawning and egg incubation under the No Action Alternative. Under the No Action Alternative, Trinity River flow and water temperature below (downstream of) Lewiston Dam would continue to be managed to maintain habitat conditions for anadromous fish. The variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment. Modeled monthly average flows would be equal to or greater than 300 cfs in all water year types and would provide suitable water depth and velocity for brown trout throughout the spawning and egg incubation period (November through April).

Seasonal operations under the No Action Alternative are expected to continue to maintain suitable habitat conditions for brown trout spawning and egg incubation in the Trinity River. Under the No Action Alternative, changes in the availability or suitability of brown trout juvenile spawning and egg incubation habitat would continue to be negligible.

Potential Changes to Brown Trout Juvenile Rearing and Emigration from Seasonal Operations

The impacts analysis period for brown trout juvenile rearing and emigration is January through December.

Seasonal operations in the Trinity River are generally expected to continue to maintain suitable habitat conditions for brown trout rearing and emigration under the No Action Alternative. Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. The flow regime included in the Trinity River ROD (USDOI 2000) is intended to provide juvenile coho salmon access to a diversity of habitats throughout the year as they grow and would also benefit rearing brown trout. Modeled monthly average flows would be equal to or greater than 300 cfs in all water year types to provide a range of suitable depth and velocity, access to cover, and other physical habitat elements to support rearing brown trout throughout the year. Relatively high flows in the spring are intended to mimic the natural snowmelt runoff hydrograph and provide access to low-velocity floodplain habitat.

Seasonal operations under the No Action Alternative are expected to continue to maintain suitable habitat conditions in most months and water year types for brown trout juvenile rearing and emigration in the Trinity River. Under current conditions, substantial changes in the availability or suitability of brown trout rearing and emigration habitat are unlikely and unlikely to have adverse impacts on brown trout.

Potential Changes to Brown Trout Adult Holding and Migration from Seasonal Operations

The impacts analysis period for brown trout adult holding and migration is January through December with migration primarily in November and December.

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for brown trout holding and migration under the No Action Alternative. Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Modeled monthly average flows would be equal to or greater than 300 cfs in all water year types to provide a range of suitable depth for passage, access to cover, and holding habitat to support adult brown trout. Seasonal flow releases under the No Action Alternative are also expected to reduce the threat of disease outbreaks for brown trout compared to current conditions by maintaining minimum flows and relatively cool water temperatures.

Seasonal operations under the No Action Alternative are expected to continue to maintain suitable habitat conditions for brown trout adult holding and migration in the Trinity River.

O.3.26 Trinity Reservoir Species

Under the No Action Alternative, releases of water into the Trinity River below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish downstream of Lewiston Dam while maintaining sufficient storage in the Trinity Reservoir for Trinity Reservoir species.

O.3.26.1 Trinity Reservoir

Potential Changes to Trinity Reservoir Fish Species Spawning and Egg Incubation from Seasonal Operations

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for both coldwater and warmwater Trinity Reservoir species spawning and egg incubation under the No Action Alternative. Under the No Action Alternative, releases of water into the Trinity River below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish while maintaining sufficient reservoir storage. Monthly average storage from January through December in all water year types would continue to provide sufficient habitat and suitable temperatures for both coldwater and warmwater Trinity Reservoir species throughout the spawning and incubation period.

Potential Changes to Trinity Reservoir Fish Species Larval and Juvenile Rearing and Emigration from Seasonal Operations

The impacts analysis period for both coldwater and warmwater fish species larval and juvenile rearing and emigration is January through December.

Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for both coldwater and warmwater Trinity Reservoir species larval and juvenile rearing and emigration under the No Action Alternative. Releases of water into the Trinity River below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish while maintaining sufficient reservoir storage. Monthly average storage from January through December in all water year types would continue to provide sufficient habitat and suitable temperatures for both coldwater and warmwater Trinity Reservoir species throughout the larval and juvenile rearing and emigration.

Potential changes to Trinity Reservoir fish species adult holding from seasonal operations

The impacts analysis period for both coldwater and warmwater fish species adult holding is January through December. Seasonal operations in the Trinity River are expected to continue to maintain suitable habitat conditions for both coldwater and warmwater Trinity Reservoir species adult holding under the No Action Alternative. Releases of water into the Trinity River below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish while maintaining sufficient reservoir storage. Monthly average storage from January through December in all water year types would continue to provide sufficient habitat and suitable water temperatures for both coldwater and warmwater Trinity Reservoir species throughout the adult holding period.

O.3.27 Central Valley Reservoir Species

Under the No Action Alternative, reservoir storage and water surface elevations will be subject to typical variability resulting from seasonal inflows from annual precipitation and snowmelt. Operational exports will be conducted to accommodate reservoir flood storage needs, power generation, water temperature management, redd dewatering adjustments, spawning and rearing habitat restoration needs, spring pule flows, minimum instream flows, and ramping rates. Reservoir storage and water surface elevations are not specifically managed to support or enhance warmwater and coldwater recreational fisheries.

O.3.27.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations

Seasonal operations of the Central Valley reservoirs are expected to continue providing suitable water surface elevations and minimum storage to support both coldwater and warmwater recreational fisheries. Some reservoirs like Folsom, Shasta, and Whiskeytown may also continue supplementing coldwater fish populations with additional planting to enhance the recreational fishery. Potential negative effects resulting from reduced inflows may lead to reduced surface water elevations and decreased storage volumes for reservoir species, however seasonal operations under the No Action Alternative are expected to have negligible effects on Central Valley reservoir species.

O.3.28 Delta-Mendota Canal/California Aqueduct Species

Under the No Action Alternative, water from the Delta would continue to be diverted through the California Aqueduct and Delta-Mendota Canal and be held for off-stream storage. Warm-water species such as black basses and striped bass support recreational fishing in the California Aqueduct. Water velocity in the canal is not specifically managed to support or enhance recreational fisheries.

O.3.28.1 Potential Changes to Delta-Mendota Canal and California Aqueduct Species from Seasonal Operations

Seasonal operations are expected to continue to support habitat conditions suitable for warm water fish species. Changes in water velocity under the No Action Alternative would result from deliberate operational changes in pumping. However, these operational changes in velocity are expected to have negligible effects on species which occur in the Delta-Mendota Canal and California Aqueduct.

O.3.29 San Luis Reservoir Species

Under the No Action Alternative, water from the Delta would continue to be diverted to San Luis Reservoir through the California Aqueduct and Delta-Mendota Canal and held for off-stream storage. Warmer water are typically pumped into the reservoir at inlets near the bottom of the reservoir, eliminating thermal stratification within the reservoir, therefore reducing potential habitat for coldwater species. Warmwater species such as black basses and striped bass support recreational fishing in the reservoir. Reservoir water surface elevations are not specifically managed to support or enhance warmwater recreational fisheries.

O.3.29.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations

Seasonal operations of San Luis Reservoir are expected to continue to support habitat conditions suitable for warmwater fish species. Changes in water surface elevations under the No Action Alternative would result from deliberate operational changes in pumping into and releases from the reservoir, however these operational changes in water surface elevation are expected to have negligible effects on warm water species which occur in San Luis Reservoir.

O.3.30 Southern Resident Killer Whale

O.3.30.1 Nearshore Pacific Ocean on the California Coast

Changes in water operations under the alternatives are expected to continue to affect Chinook salmon prey for Southern Resident Killer Whale (Southern Residents). Outlined below are expected changes under the No Action Alternative in Southern Residents' prey. Four lines of evidence were used (Salmort, XT, CVPIA SIT LCM, and DPM), this appendix provides detailed results of all models and analyses.

Based on the lines of evidence, the No Action Alternative is predicted to have an annual abundance of about 232,750 Chinook salmon that survive to adulthood or about 3,494,746 pounds of Chinook salmon biomass in the ocean available as potential prey to Southern Residents.

O.4 Alternative 1

Under Alternative 1 (Water Quality Control Plan), Reclamation and DWR operate the CVP and SWP to D-1641 and tributary specific water right requirements and agreements. Alternative 1 does not include the operational restrictions in the USFWS and NMFS 2008 and 2009 Biological Opinions Reasonable and Prudent Alternatives or 2019 Biological Opinions for the management of exports, Delta salinity, and releases from upstream facilities. Comparisons using Alternative 1 inform the effectiveness of non-flow measures versus addressing stressors by restrictions on water operations. Large investments in habitat restoration have occurred and continue, yet long-lead times for landscape level changes and salmonid lifecycles mean that many projects remain in progress with few generations of fish to assess benefits, except on Clear Creek. Reclamation would continue to operate each tributary with the same primary purposes as described in Common Components, see EIS Chapter 3, *Alternatives*.

O.4.1 Trinity River

O.4.1.1 Trinity River flows below Lewiston Dam

CalSim 3 modeling suggests that average monthly flow released at Lewiston Dam under Alternative 1 would generally be higher than or similar to flow under the No Action Alternative, except in below normal water years in March when Alternative 1 flows would be substantially lower than the No Action Alternative flow (Table O-12). Table O-12 s shows that the highest flows for both alternatives is expected primarily in May and June of all water year types and during winter, spring, and early summer of wet and above normal water years. Throughout the full simulation period, flows on average are higher under Alternative 1 in December through March, with the greatest increases (greater than 5%) in flow in February.

O.4.1.2 Trinity Reservoir Storage

CalSim 3 modeling suggests that average monthly Trinity Reservoir storage under Alternative 1 would generally be higher than storage under the No Action Alternative, except in above normal years in February, April, and July and in critically dry years July through December when Trinity Reservoir storage would be slightly lower than the No Action Alternative (Table O-13). Table O-13 shows that there are no changes between Alternative 1 and the No Action Alternative that exceed 5% in any water year type or month. Throughout the full simulation period, storage on average is slightly higher under Alternative 1 across all months.

Table O-12. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston for the No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	373	393	1,133	1,872	1,843	2,002	1,035	4,637	3,054	1,122	760	760
Above Normal (14%)	373	403	785	1,016	1,194	1,021	552	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	931	300	606	427	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	342	720	840	912	900	682	3,598	1,820	814	834	834
ALTERNATIVE 1												
Wet (28%)	373	393	1,212	1,962	1,888	2,059	1,035	4,637	3,054	1,122	760	760
Above Normal (14%)	373	404	784	1,024	1,475	1,026	553	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	960	311	610	349	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	342	747	869	965	903	682	3,598	1,820	814	834	834
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	78	90	45	57	0	0	0	0	0	0
Above Normal (14%)	0	1	-1	9	281	5	1	0	0	0	0	0
Below Normal (18%)	0	0	29	11	4	-78	0	0	0	0	0	0
Dry (24%)	0	0	0	0	0	0	0	0	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	0	0	27	28	53	2	0	0	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-13. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir Storage for the No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,656	1,658	1,709	1,764	1,945	2,061	2,239	2,194	2,105	2,008	1,879	1,745
Above Normal (14%)	1,496	1,518	1,581	1,661	1,837	2,005	2,165	2,079	1,992	1,880	1,702	1,546
Below Normal (18%)	1,263	1,295	1,392	1,536	1,640	1,773	1,900	1,817	1,740	1,602	1,432	1,298
Dry (24%)	1,060	1,100	1,244	1,385	1,492	1,619	1,706	1,606	1,513	1,364	1,199	1,088
Critically Dry (16%)	727	737	810	1,004	1,051	1,123	1,140	1,064	995	927	822	753
Full Simulation Period Average	1,279	1,299	1,386	1,496	1,623	1,745	1,864	1,788	1,704	1,589	1,442	1,320
ALTERNATIVE 1												
Wet (28%)	1,676	1,675	1,722	1,772	1,950	2,063	2,242	2,199	2,115	2,012	1,885	1,762
Above Normal (14%)	1,521	1,545	1,605	1,676	1,836	2,006	2,164	2,079	1,997	1,876	1,706	1,576
Below Normal (18%)	1,273	1,301	1,395	1,544	1,649	1,785	1,916	1,832	1,756	1,614	1,444	1,314
Dry (24%)	1,094	1,134	1,280	1,398	1,511	1,639	1,732	1,634	1,543	1,401	1,237	1,121
Critically Dry (16%)	710	720	793	1,011	1,072	1,146	1,172	1,085	1,020	920	817	736
Full Simulation Period Average	1,296	1,315	1,400	1,506	1,634	1,757	1,879	1,802	1,721	1,600	1,454	1,338
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	20	18	13	8	5	2	4	5	10	4	5	17
Above Normal (14%)	25	26	24	15	-1	1	-1	0	5	-4	4	30
Below Normal (18%)	10	6	3	8	10	13	16	15	16	13	12	16
Dry (24%)	34	34	35	13	19	20	25	28	30	37	38	33
Critically Dry (16%)	-17	-17	-17	7	21	23	32	21	25	-7	-5	-16
Full Simulation Period Average	17	16	14	10	11	11	15	14	18	11	13	17

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses.

O.4.1.3 Trinity River Water Temperatures below Lewiston Dam

Modeled average monthly water temperatures downstream of Lewiston Dam across all water year types under Alternatives 1 through 4 and the No Action Alternative are generally similar (i.e., ≤0.5°F difference) for all months, but the direction (e.g., cooler or warmer) of the difference varies between months (Figure O-10). There was not a consistent trend in the average monthly water temperature differences between the individual alternatives and the No Action Alterative per month, with a single alternative being warmer than the No Action Alternative in some months and cooler than the No Action Alternative in other months. For example, Alternative 1 was warmer than the No Action Alternative during December, February through April, June, August, and September, but it was cooler than the No Action Alternative during October, November, January, May, and July. The largest differences in the average monthly water temperature downstream of Lewiston Dam across all water year types between individual alternatives and the No Action Alternative occurred during August and September (i.e., -0.13 to 0.32°F in August and 0.18 to 0.32°F in September where a negative value indicates the temperature is cooler than the No Action Alternative).

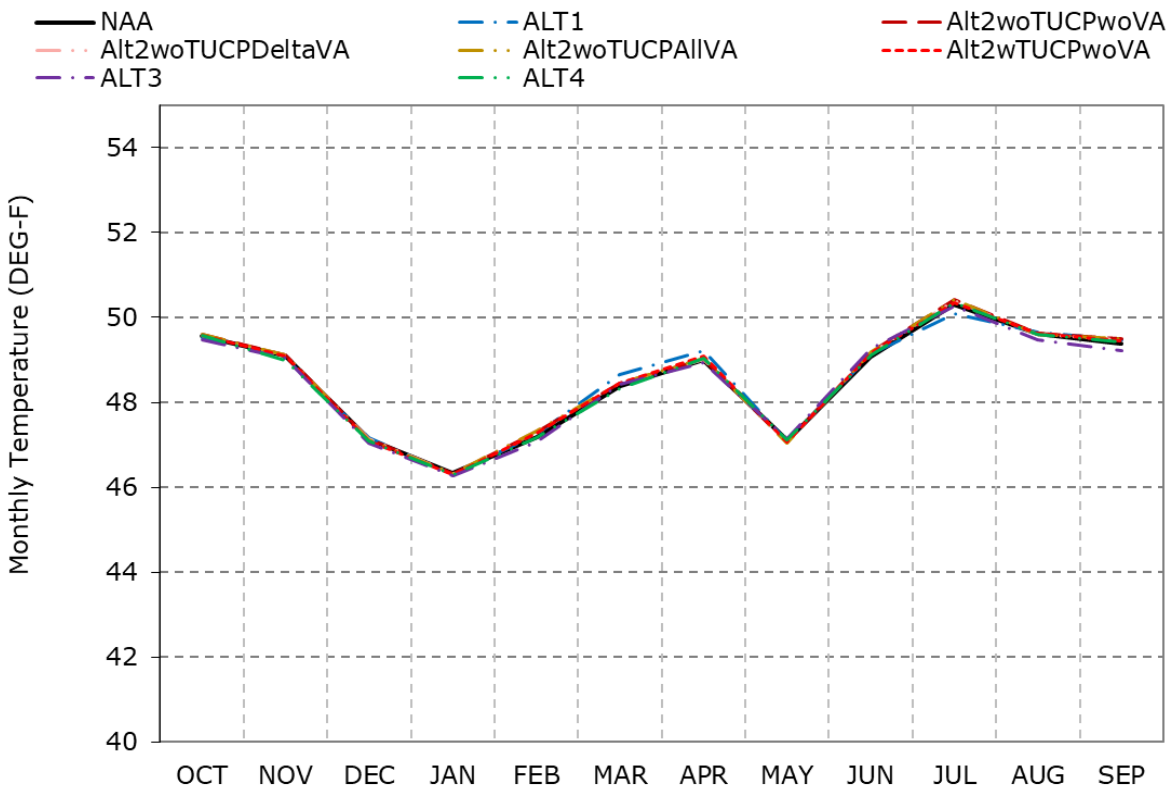


Figure O-10. Modeled Average Monthly Water Temperatures in the Trinity River below Lewiston Dam under the No Action Alternative and Action Alternatives

Differences in the average monthly water temperatures downstream of Lewiston Dam under Alternatives 1 through 4 and the No Action Alternative were more prominent when considering only specific water year types. Downstream of Lewiston Dam, average monthly water temperatures were generally lower in the average across wet water years (Figure O-11) than in the average across dry and critically dry water years (Figure O-13). In wet water years, average monthly water temperatures downstream of Lewiston Dam under Alternative 1 were similar to the No Action Alternative. However, average monthly water temperatures downstream of Lewiston Dam in wet water years under Alternative 2 Without TUCP Without VAs, Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Delta VA, Alternative 2 Without TUCP Systemwide VA, and Alternative 4 were similar to the No Action Alternative in October through January, increased relative to the No Action Alternative from February through April, were similar to the No Action Alternative from May through July, and increased relative to the No Action Alternative in August and September (Figure O-11). Average monthly water temperatures downstream of Lewiston Dam in wet water years under Alternative 3 followed a different trend than the other alternatives, with the temperatures under Alternative 3 greater than the No Action Alternative in October through December, less than the No Action Alternative in January through April, similar to the No Action Alternative from May through July, and then less than the No Action Alternative in August and September.

In dry and critically dry water years, average monthly water temperature trends downstream of Lewiston Dam were generally similar to the No Action Alternative, but the difference between some alternatives and the No Action Alterative in dry and critically dry water years was more pronounced in the spring and late summer than in the average across all water years (Figure O-13). Average monthly water temperatures downstream of Lewiston Dam in dry and critically dry water years under Alternative 1 were still similar to the No Action Alternative (i.e., ≤ 0.5°F difference), but were warmer during February through April than under the average across all water year types. Average monthly water temperatures downstream of Lewiston Dam in dry and critically dry water years under Alternative 2 Without TUCP Without VAs, Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Delta VA, Alternative 2 Without TUCP Systemwide VA, and Alternative 4 showed similar trends and were similar to the No Action Alternative (i.e., ≤ 0.5°F difference) from October through June, but the average monthly water temperatures for these alternatives increased more gradually in July and stayed higher than the No Action Alternative in August and September (Figure O-13). Average monthly water temperatures for these alternatives were 0.57 to 0.27°F cooler than the No Action Alternative in July and 0.25 to 0.65°F warmer than the No Action Alternative in August and September. Average monthly water temperatures downstream of Lewiston Dam in dry and critically dry water years under Alternative 3 followed a different trend relative to the No Action Alternative than the other alternatives, but were still similar to the No Action Alternative (i.e., ≤ 0.5°F difference).

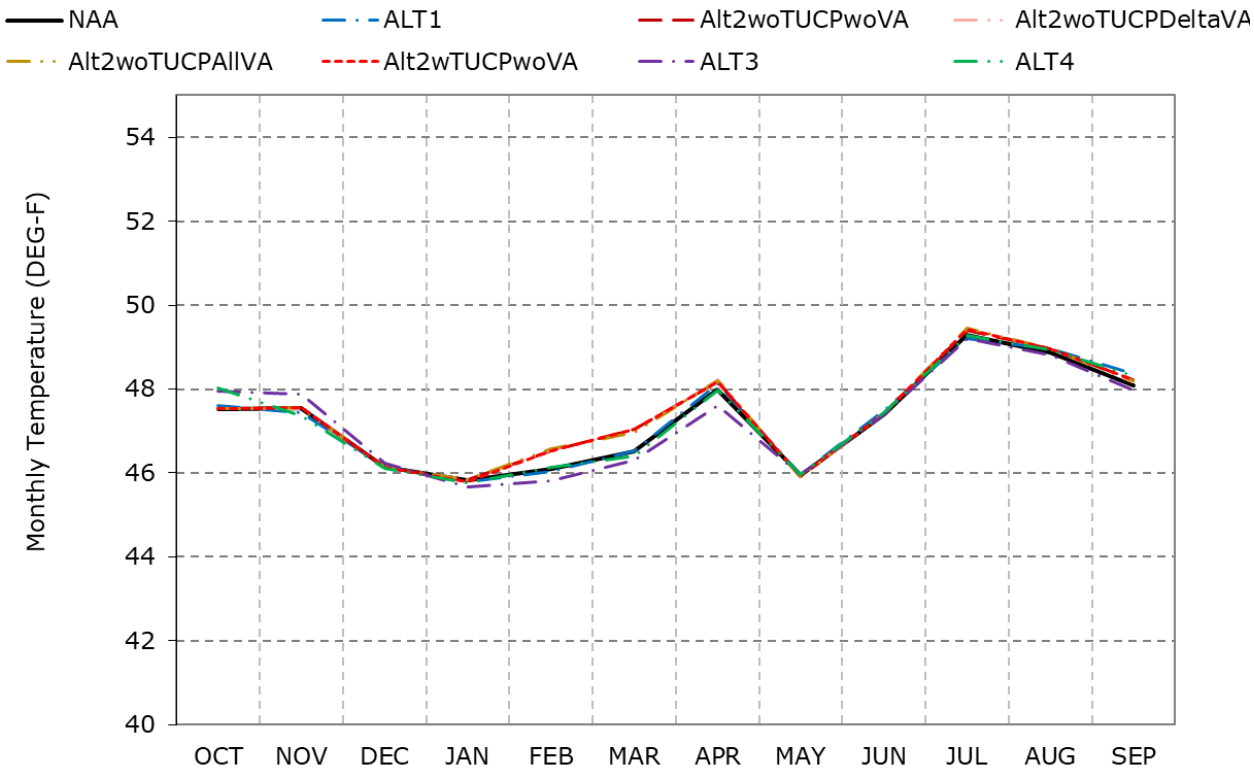


Figure O-11. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam under the No Action Alternative and the Action Alternatives in Wet Water Years

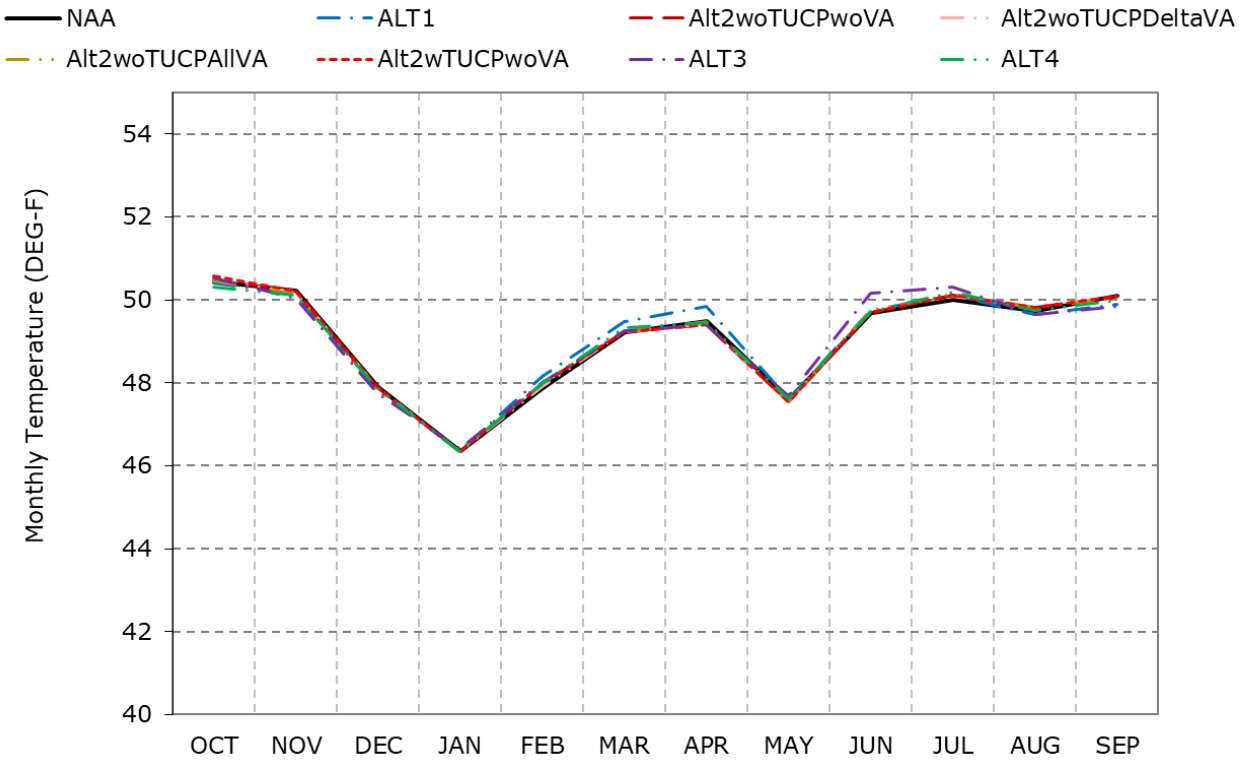


Figure O-12a. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam under the No Action Alternative and the Action Alternatives in Dry (top) and Critically Dry (bottom) Water Years

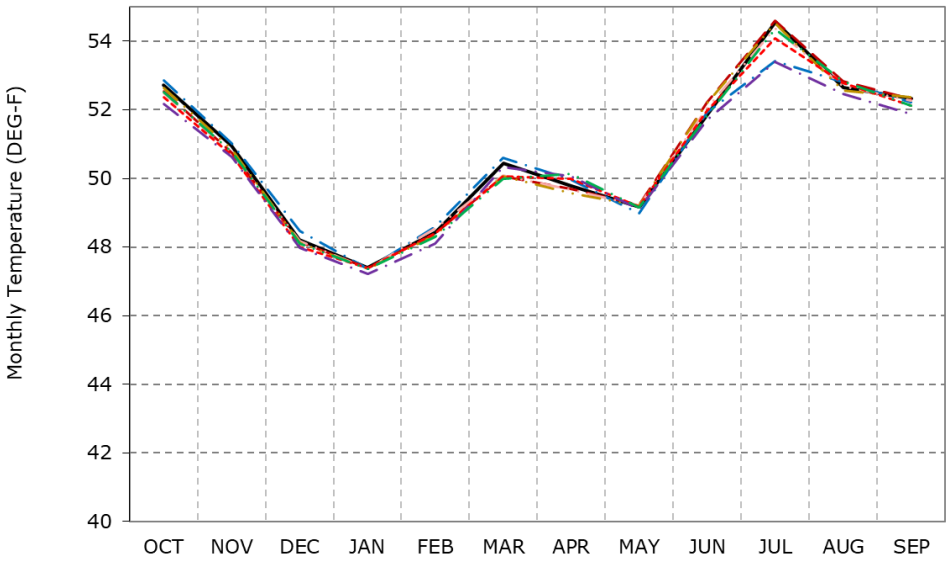


Figure O-13b. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam under the No Action Alternative and the Action Alternatives in Dry (top) and Critically Dry (bottom) Water Years

O.4.2 Sacramento River

Under all the action alternatives, flows in the upper Sacramento River result from controlled releases from Shasta Reservoir and Keswick Dam, as well as transfers from the Trinity River and natural accretions. The releases and transfers are determined by a suite of laws, regulations, contracts, and agreements to address demands of water users, requirements for water quality, and needs of fish populations throughout the river and the Delta. In particular, operations of all the action alternatives are regulated by the Water Board's D-1641 decision, which requires flow releases to meet Delta standards, and their WRO 90-5 decision, which requires coldwater releases to meet temperature targets at compliance points in the upper Sacramento River. Dry hydrologic conditions often lead to inadequate storage in Shasta Reservoir for operators to provide suitable conditions for salmonids and other native species in the upper Sacramento River. In most cases, however, water temperature rather than flow is the limiting factor creating unsuitable conditions, as discussed below. Flow releases are high during the summer to satisfy downstream demands of water users and Delta water quality, and to meet water temperature requirements of incubating winter-run Chinook salmon eggs and alevins downstream of Keswick Dam.

Alternative 1 (Water Quality Control Plan) operates the CVP and SWP to D-1641 and tributary specific water right requirements and agreements. Reclamation will operate minimum instream flows under Alternative 1 at 2,300 cfs from March through August and 3,250 cfs from September through February, with a schedule providing for flow reductions in critically dry years (WRO Order 90-5). Alternative 1 does not include specific winter or spring pulse flows. Under Alternative 1, Reclamation would make releases based on Delta requirements under D-1641, settlement contracts, and making use of available water supply for deliveries to CVP water service contractors while reducing the potential for spill. Reclamation would operate the Temperature Control Device on Shasta Reservoir, consistent with WRO Order 90-5, to target 56°F at the most downstream location feasible from May 15 through October 30 each year.

O.4.2.1 Sacramento River Flows below Keswick Dam

CalSim 3 modeling suggests that monthly average flow under Alternative 1 compared to the No Action Alternative below Keswick Dam is expected to be similar (less than 5% difference) or increased throughout the full simulation period (Table O-14). The largest increases under Alternative 1 compared to the No Action Alternative are expected in June and December of an above normal water year type. The largest decreases under Alternative 1 compared to the No Action Alternative are expected in August and September of an above normal water year type.

O.4.2.2 Sacramento River Flows below Red Bluff Diversion Dam

CalSim 3 modeling suggests that monthly average flow under Alternative 1 compared to the No Action Alternative below Red Bluff Diversion Dam is expected to be similar October through May, and may increase or decrease depending on the month June through September throughout the full simulation period (Table O-15). The largest increases in flow under Alternative 1 are expected in December of an above normal year, in June of wet, above normal, and below normal water year types, and in July of critically dry years. The largest decreases in flow under Alternative 1 are expected in August, September, and November of wet, above normal, and below normal water year types.

O.4.2.3 Sacramento River Flows at Wilkins Slough

CalSim 3 modeling suggests that monthly average flow under Alternative 1 compared to the No Action Alternative is expected to be similar December through May, and may increase or decrease depending on the month June through November throughout the full simulation period (Table O-16). The largest increases in flow under Alternative 1 are expected in June of wet, above normal, and below normal water year types, and in July of critically dry years. The largest decreases in flow under Alternative 1 are expected in August, September, and November of wet, above normal, and below normal water year types.

O.4.2.4 Sacramento River Flows at Hamilton City

CalSim 3 modeling suggests that monthly average flow under Alternative 1 compared to the No Action Alternative at Hamilton City is expected to be similar October through May, and may increase or decrease depending on the month June through September throughout the full simulation period (Table O-17). The largest increases in flow under Alternative 1 are expected in June of wet, above normal, and below normal water year types, and in July of critically dry years. The largest decreases in flow under Alternative 1 are expected in August, September, and November of wet, above normal, and below normal water year types.

Table O-14. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,453	6,575	8,760	17,717	23,928	15,969	9,265	7,358	8,719	13,608	10,371	9,177
Above Normal (14%)	6,557	7,216	5,406	10,012	16,075	9,999	5,427	7,925	10,098	15,553	11,005	8,571
Below Normal (18%)	5,525	5,011	7,696	4,912	5,278	5,012	5,325	9,308	10,409	14,159	10,770	5,608
Dry (24%)	4,809	5,025	7,991	3,399	4,693	4,137	5,592	8,051	10,950	13,138	9,106	5,524
Critically Dry (16%)	4,333	4,288	3,335	3,568	4,277	3,662	3,905	7,013	9,415	10,109	7,723	5,030
Full Simulation Period Average	5,869	5,675	7,067	8,633	11,711	8,352	6,279	7,899	9,863	13,307	9,804	6,909
ALTERNATIVE 1												
Wet (28%)	7,605	6,405	9,132	18,179	24,345	16,086	9,140	7,777	9,506	13,320	9,936	8,538
Above Normal (14%)	6,297	6,231	6,924	10,499	16,649	9,960	5,282	8,422	11,620	14,959	9,727	6,838
Below Normal (18%)	5,733	5,026	7,660	5,221	6,021	5,409	5,561	9,359	11,675	13,698	9,802	6,272
Dry (24%)	5,024	5,027	8,298	3,441	4,938	4,318	5,975	8,040	11,379	13,015	9,292	5,725
Critically Dry (16%)	4,263	4,287	3,485	3,696	4,028	3,944	4,745	7,477	9,621	11,276	7,457	4,867
Full Simulation Period Average	5,951	5,482	7,489	8,917	12,061	8,539	6,493	8,167	10,660	13,217	9,332	6,629
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	152	-169	372	462	417	117	-125	419	787	-287	-435	-639
Above Normal (14%)	-260	-986	1,518	488	574	-39	-145	497	1,522	-594	-1,278	-1,733
Below Normal (18%)	208	15	-36	310	742	397	236	51	1,266	-461	-969	664
Dry (24%)	215	1	307	42	245	181	383	-11	429	-123	186	200
Critically Dry (16%)	-69	-2	150	128	-249	283	840	464	206	1,168	-267	-163
Full Simulation Period Average	82	-192	421	284	350	187	213	268	797	-89	-473	-280

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-15. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,228	8,683	13,701	29,751	36,916	25,296	15,001	9,396	9,243	12,998	9,757	9,264
Above Normal (14%)	7,428	9,038	10,730	19,185	26,409	17,672	9,071	9,166	10,002	14,637	10,364	8,607
Below Normal (18%)	6,469	6,914	13,860	10,404	10,259	9,322	7,698	10,248	10,293	13,473	10,270	5,856
Dry (24%)	5,710	6,807	13,495	6,375	10,498	8,387	7,311	8,682	10,748	12,483	8,649	5,677
Critically Dry (16%)	4,793	5,342	6,988	5,988	7,268	5,869	4,836	7,539	9,555	10,051	7,595	5,321
Full Simulation Period Average	6,672	7,466	12,227	15,377	19,563	14,187	9,384	9,049	9,949	12,718	9,322	7,067
ALTERNATIVE 1												
Wet (28%)	8,227	8,413	13,974	30,076	37,036	25,270	14,728	9,661	9,767	12,616	9,226	8,520
Above Normal (14%)	7,011	7,949	12,133	19,527	26,667	17,486	8,767	9,504	11,251	13,946	8,988	6,765
Below Normal (18%)	6,521	6,831	13,731	10,568	10,706	9,570	7,782	10,150	11,293	12,920	9,210	6,420
Dry (24%)	5,777	6,709	13,689	6,274	10,560	8,426	7,514	8,494	10,871	12,222	8,698	5,750
Critically Dry (16%)	4,660	5,295	7,064	5,991	6,905	6,031	5,547	7,891	9,573	11,096	7,252	5,073
Full Simulation Period Average	6,614	7,182	12,549	15,522	19,670	14,233	9,443	9,164	10,483	12,519	8,747	6,680
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	-270	273	325	120	-25	-273	266	524	-382	-532	-744
Above Normal (14%)	-417	-1,089	1,402	342	257	-186	-304	338	1,249	-691	-1,376	-1,842
Below Normal (18%)	53	-83	-129	164	447	249	84	-98	1,001	-553	-1,060	564
Dry (24%)	67	-97	195	-101	62	39	203	-188	123	-261	49	73
Critically Dry (16%)	-132	-47	76	3	-363	162	712	352	18	1,045	-342	-248
Full Simulation Period Average	-57	-284	322	144	107	47	59	115	534	-199	-575	-387

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-16. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	6,747	7,468	10,397	18,705	19,917	17,996	14,436	7,416	5,607	7,544	5,925	7,204
Above Normal (14%)	5,961	7,038	9,668	15,284	18,028	16,281	11,131	6,025	5,489	8,795	6,524	6,581
Below Normal (18%)	4,873	5,672	11,096	10,852	11,463	11,209	8,152	5,869	5,299	7,459	6,026	3,788
Dry (24%)	4,113	5,375	9,640	7,139	11,119	10,068	6,993	4,676	5,632	6,501	4,502	3,592
Critically Dry (16%)	2,894	3,464	6,820	6,285	8,177	7,026	3,957	3,317	4,791	4,776	3,949	3,168
Full Simulation Period Average	5,082	5,977	9,695	12,049	14,141	12,876	9,379	5,629	5,410	7,011	5,369	4,989
ALTERNATIVE 1												
Wet (28%)	6,733	7,242	10,483	18,745	19,907	17,951	14,129	7,665	6,175	7,187	5,402	6,413
Above Normal (14%)	5,509	5,731	10,383	15,498	18,011	16,140	10,810	6,348	6,753	8,152	5,227	4,690
Below Normal (18%)	4,897	5,555	10,999	10,976	11,661	11,310	8,225	5,743	6,306	6,934	5,021	4,267
Dry (24%)	4,218	5,178	9,744	7,049	11,175	10,095	7,168	4,537	5,771	6,269	4,531	3,640
Critically Dry (16%)	2,846	3,347	6,866	6,312	8,011	7,160	4,588	3,669	4,837	5,771	3,763	2,985
Full Simulation Period Average	5,032	5,632	9,841	12,096	14,158	12,890	9,405	5,744	5,968	6,829	4,838	4,571
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-13	-225	86	40	-10	-45	-307	250	567	-358	-523	-792
Above Normal (14%)	-452	-1,307	715	215	-17	-141	-320	323	1,265	-644	-1,296	-1,891
Below Normal (18%)	24	-117	-97	124	198	101	73	-126	1,007	-526	-1,005	479
Dry (24%)	105	-197	105	-90	56	27	175	-139	139	-232	28	48
Critically Dry (16%)	-48	-117	46	27	-166	134	631	351	46	995	-186	-183
Full Simulation Period Average	-49	-345	146	46	17	14	25	115	558	-181	-532	-418

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-17. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,774	9,060	15,844	36,160	43,468	29,725	17,650	8,737	7,593	10,522	8,015	8,486
Above Normal (14%)	7,022	9,205	13,122	23,971	31,918	21,265	10,557	7,853	7,987	12,017	8,577	7,776
Below Normal (18%)	6,086	7,165	17,022	13,255	12,647	11,442	8,573	8,564	8,090	10,753	8,376	5,047
Dry (24%)	5,424	6,996	15,816	7,835	13,272	10,306	7,768	6,767	8,428	9,720	6,726	4,808
Critically Dry (16%)	4,248	5,011	8,610	7,004	8,624	6,911	4,760	5,640	7,496	7,846	6,133	4,536
Full Simulation Period Average	6,264	7,638	14,556	18,868	23,481	16,939	10,589	7,614	7,923	10,152	7,548	6,253
ALTERNATIVE 1												
Wet (28%)	7,770	8,790	16,119	36,486	43,590	29,702	17,379	9,002	8,122	10,144	7,488	7,738
Above Normal (14%)	6,599	8,113	14,516	24,311	32,175	21,081	10,251	8,190	9,238	11,333	7,209	5,929
Below Normal (18%)	6,134	7,079	16,893	13,418	13,092	11,692	8,656	8,470	9,094	10,205	7,324	5,606
Dry (24%)	5,498	6,901	16,003	7,735	13,332	10,345	7,967	6,583	8,554	9,463	6,777	4,879
Critically Dry (16%)	4,175	4,970	8,685	7,008	8,265	7,070	5,458	5,988	7,514	8,886	5,844	4,342
Full Simulation Period Average	6,215	7,354	14,875	19,013	23,588	16,986	10,645	7,730	8,460	9,957	6,986	5,872
ALTERNATIVE 1 minus No Action Alternative												
Wet (28%)	-4	-270	275	326	123	-23	-271	265	529	-378	-527	-748
Above Normal (14%)	-423	-1,093	1,394	340	257	-184	-306	337	1,251	-684	-1,368	-1,847
Below Normal (18%)	49	-86	-129	163	444	250	83	-94	1,004	-548	-1,051	559
Dry (24%)	74	-95	187	-100	60	38	198	-184	126	-257	51	71
Critically Dry (16%)	-73	-41	74	4	-359	159	698	348	19	1,039	-289	-194
Full Simulation Period Average	-49	-284	319	145	107	48	55	116	537	-195	-562	-381

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.4.3 Bay-Delta

In the winter and spring, Reclamation and DWR typically export excess water. Excess water conditions occur when releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley in-basin uses and exports. Actions to minimize entrainment of listed fish into the south Delta and at the Jones and Banks pumping plants limit the export of excess water. Exports during the winter and spring reduce the reliance on conveying previously stored water in the summer and fall for south-of-Delta water supply needs. In dry conditions, Reclamation and DWR may need to increase releases from upstream reservoirs beyond what is needed to meet minimum flow requirements to meet water quality or outflow requirements in the Delta.

During the summer, the CVP and SWP convey previously stored water through the Delta for export at the Jones Pumping Plant, Banks Pumping Plant, and other Delta facilities. Delta operations during the summer typically focus on maintaining salinity and meeting Delta outflow objectives while maximizing exports with the available water supply. In addition, the CVP and SWP make upstream reservoir releases for water temperature management and instream flows, which may be available for export after outflow, salinity, and in-Delta needs have been met.

In the fall, operations are adjusted to meet salinity, Delta outflow requirements, and peak demands from CVPIA wildlife refuges. Upstream and in-Delta demands typically decrease and accretions within the system typically increase. When water is available and not required for salinity and Delta outflow requirements, late summer and fall provide an opportunity to export water and start filling San Luis Reservoir for the next water year. When conditions are dry, there is little opportunity for exports. Releases from upstream reservoirs generally decrease to conserve water in storage for the next year. On occasion, releases for flood conservation pool or redds protection may occur and result in additional flows into the Delta.

Alternative 1 (Water Quality Control Plan) operates the CVP and SWP to D-1641 and tributary specific water right requirements and agreements. Alternative 1 does not include OMR criteria which would result in lower Delta outflows under Alternative 1. Additionally, DWR would not operate to the spring outflow in the 2020 Incidental Take Permit for the SWP. Reclamation and DWR would operate to achieve X2 westward locations required by D-1641's outflow and salinity objectives.

O.4.3.1 Delta X2

CalSim3 modeling suggests that the estimated X2 position under Alternative 1 when compared to the No Action Alternative increases in the early fall (September–October) during the wet and above normal water year type. X2 position is similar across all other months and water year types (Table O-18). Table O-18 shows that the most landward position of X2 is expected primarily during late summer to fall of critically dry water years for both alternatives. Throughout the full simulation period, the X2 position did not greatly change when comparing Alternative 1 and the No Action Alternative.

O.4.3.2 Delta Exports

CalSim3 modeling suggests that the total exports of the SWP and CVP under Alternative 1 when compared to the No Action Alternative generally increase from September–October and December–June. Exports decrease in November during wet and above normal water year types, in August during the below normal water year type and September during the dry water year type (Table O-19). Table O-19 shows total exports are highest in summer during wet years for the No Action Alternative, but for Alternative 1, total exports are highest in winter during wet years. Throughout the full simulation period, total exports for Alternative 1 when compared to the No Action Alternative was higher from September to October and from December to June and lower in November.

O.4.3.3 Delta Outflow

Under Alternative 1 when compared to the No Action Alternative, total Delta outflow generally increases in June across most water year types and generally decreases the rest of the year for most water year types (Table O-20). Table O-20 shows outflow is highest in the month of February for both alternatives during the wet water year type. Outflow is the lowest late summer to fall during the critically dry water year type. Throughout the full simulation period, total Delta outflow was lower for Alternative 1 compared to the No Action Alternative from July to October, December to January, and May. Total Delta outflow was higher in June across the full simulation period.

O.4.3.4 Delta OMR

CalSim3 modeling suggests that Old and Middle River combined flows for Alternative 1 when compared to the No Action Alternative is generally more negative from September to October and December to June for most water year types. OMR flows were less negative in November during the wet and above normal water year types, in August during the below normal water year type, and September during the dry water year type (Table O-21). Table O-21 shows the most negative OMR flows are expected during August of the above normal water year type for both alternatives and the least negative during April of the critically dry water year type for both alternatives. Throughout the full simulation period, when comparing Alternative 1 and the No Action Alternative, OMR flows were more negative from September to November and from December to June and more positive in November.

O.4.3.5 Sacramento River at Rio Vista

CalSim3 modeling suggests that average flows in the Sacramento River at Rio Vista under Alternative 1 compared to the No Action Alternative are similar or increased from February through June and similar or decreased July through January (Table O-22). The greatest reductions are expected during September of a wet water year type under Alternative 1 compared to the No Action Alternative. The greatest increase is expected during April of a critically dry water year type under Alternative 1 compared to the No Action Alternative.

Table O-18. CalSim 3 Estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 1 and Differences between Them

Alternative	X2 Position (km)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	79	80	74	56	54	55	58	63	72	78	83	79
Above Normal (14%)	80	83	77	62	57	57	62	69	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	68	72	80	83	87	90
Dry (24%)	91	88	78	79	69	68	72	77	82	86	89	92
Critically Dry (16%)	94	93	85	82	77	77	83	87	89	92	93	93
Full Simulation Period Average	86	86	77	69	64	64	68	73	79	83	87	86
ALTERNATIVE 1												
Wet (28%)	86	83	76	57	54	56	59	64	72	79	84	86
Above Normal (14%)	88	87	78	64	57	58	63	70	76	80	85	88
Below Normal (18%)	89	88	75	73	67	66	69	74	79	83	86	89
Dry (24%)	89	86	79	82	71	69	73	78	82	86	89	91
Critically Dry (16%)	92	91	85	85	79	77	79	84	87	90	92	92
Full Simulation Period Average	89	86	78	71	65	64	68	73	78	83	87	89
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	7	3	1	1	0	0	1	1	0	0	2	**7**
Above Normal (14%)	8	3	1	2	1	1	1	1	-1	0	2	**8**
Below Normal (18%)	-1	-1	1	3	1	1	1	2	-1	0	0	-1
Dry (24%)	-1	-2	1	3	2	1	1	1	0	0	0	-1
Critically Dry (16%)	-2	-2	0	2	2	-1	-3	-3	-2	-2	-1	0
Full Simulation Period Average	2	0	1	2	1	1	0	0	-1	0	1	3

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-19. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,586	10,782	8,504	9,217	9,986	8,557	7,132	6,750	7,386	10,597	10,891	8,364
Above Normal (14%)	5,987	10,099	8,039	7,441	8,282	6,935	4,259	4,336	5,864	10,356	10,686	5,703
Below Normal (18%)	5,887	7,526	7,027	6,408	7,112	6,214	3,808	3,669	5,502	9,913	8,767	6,714
Dry (24%)	4,225	6,067	5,475	6,216	6,321	5,760	3,082	2,916	4,929	7,138	4,116	5,320
Critically Dry (16%)	2,715	2,579	5,724	5,078	5,559	4,421	2,045	2,124	1,895	1,631	1,637	2,660
Full Simulation Period Average	5,503	7,732	7,024	7,080	7,642	6,575	4,345	4,197	5,365	8,175	7,373	6,051
ALTERNATIVE 1												
Wet (28%)	10,359	10,056	10,164	12,805	12,154	10,112	7,817	8,507	8,339	10,332	10,916	10,735
Above Normal (14%)	9,193	8,461	10,371	12,450	11,681	10,302	5,951	6,116	7,617	10,832	11,026	9,888
Below Normal (18%)	6,218	7,268	9,855	11,276	9,756	9,627	5,243	4,965	6,618	9,826	8,036	7,651
Dry (24%)	4,848	6,252	8,280	9,297	9,441	7,862	3,896	3,900	5,159	7,078	4,204	4,748
Critically Dry (16%)	2,700	2,823	7,085	7,395	7,185	4,254	2,580	2,443	2,149	2,156	1,556	2,899
Full Simulation Period Average	6,967	7,317	9,226	10,773	10,210	8,574	5,314	5,459	6,174	8,222	7,305	7,371
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	2,773	-726	1,660	3,588	2,168	1,554	685	1,757	953	-265	25	2,371
Above Normal (14%)	3,206	-1,638	2,333	5,009	3,399	3,366	1,693	1,780	1,753	476	340	4,185
Below Normal (18%)	331	-259	2,828	4,867	2,644	3,413	1,435	1,296	1,115	-87	-731	937
Dry (24%)	623	185	2,805	3,081	3,120	2,102	815	984	230	-60	88	-571
Critically Dry (16%)	-15	244	1,361	2,317	1,626	-167	535	319	254	525	-80	238
Full Simulation Period Average	1,464	-415	2,201	3,692	2,568	1,999	968	1,262	809	46	-69	1,319

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-20. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,918	12,055	30,736	96,898	122,709	90,897	54,587	31,188	13,556	9,410	6,009	11,294
Above Normal (14%)	8,664	7,873	21,249	53,164	71,004	58,493	27,859	17,453	9,163	10,682	6,287	10,956
Below Normal (18%)	5,366	6,747	30,789	25,764	29,373	26,423	19,249	15,376	7,772	8,121	4,144	3,679
Dry (24%)	5,887	9,013	30,407	13,571	27,568	19,839	14,134	10,846	7,191	5,232	3,826	3,213
Critically Dry (16%)	3,094	5,758	11,444	10,903	15,095	10,560	6,745	5,961	4,141	3,217	3,030	3,554
Full Simulation Period Average	6,640	8,798	26,350	44,213	58,618	44,847	27,121	17,500	8,866	7,363	4,712	6,698
ALTERNATIVE 1												
Wet (28%)	5,856	12,506	29,742	94,173	120,781	89,223	53,233	29,577	14,302	8,614	4,329	5,628
Above Normal (14%)	4,900	8,194	21,015	49,669	68,038	54,138	24,952	16,141	10,325	8,524	4,002	4,283
Below Normal (18%)	4,594	6,333	27,910	21,280	28,660	23,810	17,960	13,920	9,368	6,528	4,213	3,775
Dry (24%)	5,587	8,830	27,924	10,562	25,327	17,643	13,764	10,258	7,273	5,000	3,516	3,110
Critically Dry (16%)	3,046	4,967	10,240	8,437	13,141	11,073	8,867	5,965	5,254	4,000	3,018	3,000
Full Simulation Period Average	4,999	8,735	24,741	41,037	56,684	42,853	26,353	16,463	9,723	6,620	3,858	4,081
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-3,062	451	-994	-2,724	-1,928	-1,675	-1,354	-1,612	747	-796	-1,680	-5,666
Above Normal (14%)	-3,764	321	-234	-3,495	-2,966	-4,355	-2,907	-1,312	1,162	-2,159	-2,285	-6,673
Below Normal (18%)	-772	-413	-2,879	-4,485	-713	-2,614	-1,289	-1,456	1,596	-1,593	69	96
Dry (24%)	-300	-183	-2,483	-3,009	-2,240	-2,196	-370	-588	82	-232	-310	-103
Critically Dry (16%)	-49	-791	-1,204	-2,466	-1,954	513	2,122	4	1,113	783	-13	-554
Full Simulation Period Average	-1,640	-63	-1,608	-3,176	-1,934	-1,994	-767	-1,037	857	-742	-854	-2,617

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-21. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	-6,128	-8,400	-5,569	-2,718	-1,706	-1,261	-1,861	-1,095	-4,159	-9,708	-10,116	-7,642
Above Normal (14%)	-4,935	-8,399	-5,963	-4,302	-3,528	-3,169	-1,650	-2,348	-4,778	-10,023	-10,386	-5,854
Below Normal (18%)	-5,152	-6,123	-4,900	-4,312	-4,100	-3,658	-2,060	-2,114	-4,859	-9,847	-9,043	-6,759
Dry (24%)	-3,644	-4,859	-3,704	-4,442	-4,031	-3,933	-2,095	-2,204	-4,796	-8,003	-4,819	-5,490
Critically Dry (16%)	-2,539	-1,982	-4,330	-3,630	-3,692	-3,053	-1,079	-1,748	-2,272	-2,668	-2,463	-3,002
Full Simulation Period Average	-4,639	-6,178	-4,875	-3,786	-3,268	-2,888	-1,798	-1,825	-4,222	-8,241	-7,465	-5,974
ALTERNATIVE 1												
Wet (28%)	-8,897	-7,777	-7,069	-6,055	-3,608	-2,689	-2,794	-2,814	-4,905	-9,470	-10,093	-9,909
Above Normal (14%)	-8,113	-6,979	-8,113	-8,831	-6,594	-6,252	-4,060	-3,955	-6,329	-10,392	-10,680	-9,683
Below Normal (18%)	-5,641	-5,865	-7,474	-8,743	-6,481	-6,710	-3,546	-3,118	-5,807	-9,702	-8,277	-7,586
Dry (24%)	-4,304	-5,040	-6,279	-7,242	-6,844	-5,793	-2,810	-2,889	-4,935	-7,850	-4,905	-4,936
Critically Dry (16%)	-2,467	-2,163	-5,598	-5,732	-5,161	-2,902	-1,660	-1,984	-2,397	-3,345	-2,497	-3,252
Full Simulation Period Average	-6,126	-5,814	-6,888	-7,161	-5,568	-4,691	-2,929	-2,913	-4,873	-8,272	-7,388	-7,201
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-2,770	623	-1,499	-3,336	-1,902	-1,429	-934	-1,719	-746	237	22	-2,267
Above Normal (14%)	-3,178	1,421	-2,149	-4,529	-3,065	-3,083	-2,409	-1,606	-1,551	-369	-294	-3,830
Below Normal (18%)	-490	259	-2,574	-4,432	-2,382	-3,052	-1,486	-1,004	-948	145	766	-828
Dry (24%)	-660	-181	-2,575	-2,799	-2,813	-1,860	-715	-684	-139	153	-86	554
Critically Dry (16%)	72	-181	-1,267	-2,103	-1,469	150	-581	-236	-125	-677	-33	-250
Full Simulation Period Average	-1,488	364	-2,014	-3,374	-2,301	-1,803	-1,131	-1,089	-650	-31	77	-1,227

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-22. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River at Rio Vista for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,929	13,097	29,134	82,363	104,439	73,383	40,479	20,772	9,466	11,109	9,638	11,382
Above Normal (14%)	7,795	10,558	22,225	47,116	62,080	48,912	20,595	13,844	7,846	13,276	10,441	10,213
Below Normal (18%)	6,147	8,224	29,745	23,742	25,296	22,329	14,058	12,234	7,154	11,407	8,272	6,178
Dry (24%)	6,377	9,250	27,844	13,212	25,067	17,799	11,076	9,263	7,324	8,513	5,224	5,046
Critically Dry (16%)	3,621	4,344	12,645	10,561	13,992	9,893	4,748	5,310	3,824	3,870	3,391	3,869
Full Simulation Period Average	6,849	9,603	25,425	38,792	50,742	37,269	20,166	13,029	7,406	9,685	7,446	7,559
ALTERNATIVE 1												
Wet (28%)	8,020	12,854	28,707	83,211	104,496	73,282	40,208	21,028	10,492	10,365	8,470	9,188
Above Normal (14%)	7,174	9,674	23,077	48,147	62,207	48,080	20,314	14,219	9,732	11,660	9,026	8,450
Below Normal (18%)	5,840	7,471	28,978	23,512	26,947	22,957	14,271	11,850	8,907	10,168	7,703	6,823
Dry (24%)	6,476	9,379	27,262	12,234	25,798	17,613	11,311	9,359	7,415	8,206	5,033	4,555
Critically Dry (16%)	3,649	4,293	11,587	9,517	13,592	10,117	7,055	5,580	4,658	4,865	3,423	3,755
Full Simulation Period Average	6,474	9,290	24,997	38,731	51,185	37,228	20,514	13,150	8,428	9,113	6,777	6,678
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-909	-242	-427	848	57	-101	-270	256	1,026	-744	-1,168	-2,195
Above Normal (14%)	-621	-884	852	1,031	127	-832	-281	376	1,886	-1,616	-1,415	-1,763
Below Normal (18%)	-307	-753	-767	-231	1,651	629	214	-384	1,753	-1,238	-569	644
Dry (24%)	99	128	-582	-978	731	-186	234	95	91	-307	-190	-491
Critically Dry (16%)	27	-51	-1,058	-1,044	-400	224	2,307	270	835	995	32	-114
Full Simulation Period Average	-375	-313	-428	-62	442	-41	349	121	1,022	-572	-668	-881

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.4.4 Clear Creek

Under all the action alternatives, flows in Clear Creek result from controlled releases from Whiskeytown Dam, as well as transfers from the Trinity River and natural accretions. The releases and transfers are determined by a suite of laws, regulations, contracts, and agreements to address demands of water users, requirements for water quality, and needs of fish populations throughout the river and the Delta. In particular, operations of all the action alternatives are regulated by CVP and fisheries management priority decisions which will always require temperature regulation; depending on the alternative, commitment to additional priorities vary. Dry hydrologic conditions often lead to inadequate storage in Whiskeytown Lake for operators to provide suitable conditions for salmonids and other native species in Clear Creek. In most cases, however, water temperature rather than flow is the limiting factor creating unsuitable conditions.

Flow releases are strategically high at summer and fall to satisfy downstream demands of irrigation and other beneficial uses including hydroelectric power generation, re-establishment of Central Valley spring-run Chinook salmon and California Central Valley steelhead, recreation, and upper Sacramento River temperature control. Starting in November, Reclamation will draw down Whiskeytown Lake to create flood management space, generally refilling in April or May. On occasion, imports of Trinity River water to Whiskeytown Lake may be suspended to avoid aggravating high flow conditions in the Sacramento Basin. During the summer and early fall, Reclamation operates to provide lake elevations as full as practical for recreation. Summer and fall imports help maintain Whiskeytown Lake elevations, provide cool water for releases to Clear Creek for water temperature control objectives, decrease residence time in Lewiston Lake for Trinity River temperature control, and help maintain water temperature objectives in the Sacramento River by supplying water to Keswick Reservoir.

Alternative 1 (Water Quality Control Plan) operates the CVP and SWP to D-1641 and tributary specific water right requirements and agreements. Reclamation will operate minimum instream flows at 50 cfs from January through October and 100 cfs in normal water years and 70 cfs on critical water years from November through December as directed by the Instream Flow Preservation Agreement. Alternative 1 does not include specific winter or spring pulse flows. while there is no specific requirement in any Water Board WROs under Alternative 1, Reclamation would target Whiskeytown Dam releases to not exceed the mean daily temperatures at Igo gauge of 61°F from June 1 through August 15, 60°F from August 16 through September 15, and 56°F from Sept 15 through Nov 15. In dry, critical, or import curtailment years, Reclamation may not be able to meet these water temperatures and will operate Whiskeytown Dam as close to these water temperatures as practicable within the constraints of minimum instream flows.

O.4.4.1 Clear Creek below Whiskeytown Dam

CalSim 3 modeling suggests that average monthly flow below Whiskeytown Dam under Alternative 1 would be substantially lower than flow under No Action Alternative throughout the full simulation period (Table O-23). The largest decreases under Alternative 1 compared to the No Action Alternative are expected in February, April through June, and October.

Table O-23. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	200	200	200	305	494	300	200	200	318	150	150	150
Above Normal (14%)	200	200	200	193	365	200	200	200	318	150	150	150
Below Normal (18%)	200	190	192	194	339	200	200	200	318	150	150	142
Dry (24%)	200	200	200	194	232	192	196	200	318	150	150	150
Critically Dry (16%)	117	100	143	177	169	166	153	150	225	145	141	137
Full Simulation Period Average	187	183	190	222	333	221	192	192	303	149	149	146
ALTERNATIVE 1												
Wet (28%)	50	100	100	167	195	155	50	50	50	50	50	50
Above Normal (14%)	50	100	100	50	50	50	50	50	50	50	50	50
Below Normal (18%)	50	96	98	50	50	50	50	50	50	50	50	47
Dry (24%)	50	100	100	50	50	50	50	50	50	50	50	50
Critically Dry (16%)	41	55	72	50	50	50	50	50	50	50	45	41
Full Simulation Period Average	49	93	95	83	91	79	50	50	50	50	49	48
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-150	-100	-100	-137	-299	-145	-150	-150	-268	-100	-100	-100
Above Normal (14%)	-150	-100	-100	-143	-315	-150	-150	-150	-268	-100	-100	-100
Below Normal (18%)	-150	-94	-94	-144	-289	-150	-150	-150	-268	-100	-100	-94
Dry (24%)	-150	-100	-100	-144	-182	-142	-146	-150	-268	-100	-100	-100
Critically Dry (16%)	-76	-44	-71	-127	-119	-116	-103	-100	-175	-95	-95	-96
Full Simulation Period Average	-139	-91	-95	-139	-243	-141	-142	-142	-253	-99	-99	-98

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.4.5 American River

Under all the action alternatives, flows in the American River result from controlled releases from Folsom Reservoir and Lake Natoma, as well as natural accretions. The releases and transfers are determined by a suite of laws, regulations, contracts, and agreements to address demands of water users, requirements for water quality, and needs of fish populations throughout the river and the Delta. In particular, operations of all the action alternatives are regulated by the Water Board's D-1641 decision, which requires flow releases to meet Delta standards, which requires coldwater releases to meet water temperature targets at compliance points and salmonid life cycle needs; however, additional management commitments may be incorporated depending on the alternative. Dry hydrologic conditions often lead to inadequate storage in Folsom Reservoir and Lake Natoma for operators to provide suitable conditions for salmonids and other native species in the San Joaquin River. In most cases, however, water temperature rather than flow is the limiting factor creating unsuitable conditions, as discussed below. Flow releases are high during the summer to satisfy downstream demands of flood control, M&I and agricultural water supplies, hydroelectric power generation, steelhead and fall-run Chinook salmon, recreation, and Delta water quality.

Alternative 1 (Water Quality Control Plan) operates the CVP and SWP to D-1641 and tributary specific water right requirements and agreements. D-893 established that the minimum allowable flows in the Lower American River at H Street Bridge, in the interest of fish conservation, should not ordinarily fall below 250 cfs between January 1 and September 15 or below 500 cfs at other times. Alternative 1 does not include specific winter or spring pulse flows. Alternative 1 also does not include redd dewatering adjustments. Under Alternative 1, Reclamation would operate the Folsom Dam temperature control shutters in the same manner as in the No Action Alternative. Reclamation would implement the Automated Temperature Selection Procedure (ATSP). Each ATSP schedule determines a monthly series of water temperature targets at the Watt Avenue bridge. Schedule 1 has a water temperature upper limit of 63°F from May through September, and 56°F in October and November. Schedules 2 through 77 each represent a change in a single month's upper temperature limit by 1.0°F. Schedule 78 has a water temperature upper limit of 72°F from May through November. The ATSP may be modified for Schedule 28 or higher, the Temperature Management Plan may consider a temperature location at Hazel Avenue; for greater than 65°F at Hazel Avenue bridge for May through September, the Temperature Management Plan would include an evaluation of whether modified Folsom Reservoir operations could support an improved temperature schedule; for greater than 68°F at Hazel Avenue for May through September, the Temperature Management Plan would include an evaluation of whether modified Folsom Reservoir operations could support an improved temperature schedule and evaluate a power bypass during the summer and/or fall; for greater than 56°F at Hazel Avenue in November, the Temperature Management Plan would evaluate a power bypass.

O.4.5.1 American River for Folsom Reservoir Storage

CalSim 3 modeling suggests that average volume of Folsom Reservoir Storage under Alternative 1 compared to the No Action Alternative would increase September through January and be similar or decrease February through July (Table O-24). The largest increases are expected in January of a dry water year type and November of an above normal water year type. Decreases to storage volume greater than a 5% are not expected under Alternative 1 compared to the No Action Alternative.

O.4.5.2 American River below Nimbus Dam

CalSim 3 modeling suggests that average monthly flows below Nimbus Dam are expected to have the greatest increases in June and greatest decreases in September under Alternative 1 compared to the No Action Alternative (Table O-25). The largest increases in flow in June of below normal water year types and April of critically dry year types when compared to the No Action Alternative. The largest flow decreases are expected in September of dry and critically dry water year types when compared to the No Action Alternative.

O.4.5.3 American River at H Street

CalSim 3 modeling suggests that average monthly flows at H street are expected to have the greatest increases in June and the greatest decreases in September under Alternative 1 compared to the No Action Alternative (Table O-26). The largest increases in flow under Alternative 1 are expected in June of below normal water year types and in April of critically dry year types when compared to the No Action Alternative. The largest decreases in flow are expected in September of dry and critically dry water year types when compared to the No Action Alternative.

Table O-24. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	621	533	532	567	567	750	890	947	923	781	693	654
Above Normal (14%)	484	447	502	557	565	745	879	932	858	633	570	518
Below Normal (18%)	454	433	485	540	560	711	836	846	790	576	502	476
Dry (24%)	436	439	470	472	518	633	716	725	657	532	471	447
Critically Dry (16%)	341	318	430	430	452	503	529	524	500	440	376	362
Full Simulation Period Average	484	447	489	516	535	675	779	806	758	609	537	507
ALTERNATIVE 1												
Wet (28%)	644	558	564	567	567	751	894	952	904	794	717	689
Above Normal (14%)	546	534	557	566	567	756	887	935	839	665	618	588
Below Normal (18%)	490	508	547	561	557	738	860	864	757	597	524	508
Dry (24%)	501	496	531	560	557	688	772	770	689	549	497	521
Critically Dry (16%)	348	349	453	504	529	580	529	547	494	431	362	368
Full Simulation Period Average	523	499	535	554	557	707	799	825	751	624	559	551
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	23	25	32	0	0	1	4	6	-19	13	24	35
Above Normal (14%)	62	87	55	9	2	11	8	4	-19	32	48	70
Below Normal (18%)	36	75	62	21	-3	26	23	18	-34	21	23	31
Dry (24%)	65	57	61	88	40	55	56	45	32	17	26	74
Critically Dry (16%)	7	31	23	74	76	77	0	23	-6	-9	-14	6
Full Simulation Period Average	39	52	46	38	21	32	20	20	-7	15	22	44

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-25. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for American River below Nimbus Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,870	4,067	4,854	11,628	12,283	7,659	6,803	6,359	3,663	3,631	2,804	2,514
Above Normal (14%)	1,893	2,418	3,339	6,518	7,463	4,965	3,295	3,324	3,311	4,618	2,260	2,283
Below Normal (18%)	1,578	2,012	4,112	2,926	4,355	2,781	2,822	2,947	2,778	4,557	2,449	1,750
Dry (24%)	1,227	2,276	5,167	1,667	3,197	2,077	2,172	2,492	2,598	2,910	1,968	1,529
Critically Dry (16%)	761	1,347	911	1,368	1,759	1,149	970	1,302	1,425	1,613	1,689	1,016
Full Simulation Period Average	1,500	2,612	3,977	5,314	6,317	4,022	3,551	3,583	2,841	3,440	2,285	1,868
ALTERNATIVE 1												
Wet (28%)	2,057	4,044	4,732	11,839	12,283	7,635	6,754	6,338	4,085	3,102	2,634	2,321
Above Normal (14%)	1,942	1,997	3,850	6,859	7,598	4,809	3,350	3,394	3,698	3,777	1,999	1,917
Below Normal (18%)	1,461	1,399	4,325	3,082	4,795	2,299	2,872	3,027	3,648	3,676	2,420	1,600
Dry (24%)	1,369	2,402	5,107	1,826	4,060	1,832	2,155	2,660	2,812	3,139	1,824	729
Critically Dry (16%)	732	928	1,053	1,115	1,719	1,134	2,259	927	1,900	1,659	1,766	689
Full Simulation Period Average	1,568	2,399	4,065	5,446	6,616	3,846	3,756	3,581	3,297	3,078	2,173	1,491
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	187	-23	-121	211	0	-24	-49	-21	422	-530	-170	-193
Above Normal (14%)	49	-421	512	341	135	-156	55	70	387	-841	-261	-366
Below Normal (18%)	-117	-613	213	156	440	-482	51	80	870	-880	-29	-151
Dry (24%)	141	126	-60	158	863	-245	-17	168	214	229	-144	-800
Critically Dry (16%)	-29	-420	143	-254	-40	-15	1,290	-375	475	46	78	-327
Full Simulation Period Average	68	-213	88	132	299	-176	205	-1	456	-362	-112	-377

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-26. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the American River at H street for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,769	4,000	4,824	11,646	12,307	7,643	6,758	6,245	3,516	3,454	2,635	2,367
Above Normal (14%)	1,783	2,340	3,332	6,539	7,493	4,921	3,216	3,200	3,141	4,416	2,082	2,131
Below Normal (18%)	1,467	1,936	4,092	2,902	4,314	2,732	2,736	2,811	2,598	4,344	2,260	1,613
Dry (24%)	1,131	2,200	5,124	1,625	3,176	2,012	2,077	2,351	2,416	2,705	1,777	1,388
Critically Dry (16%)	647	1,251	905	1,303	1,712	1,075	862	1,165	1,244	1,416	1,495	867
Full Simulation Period Average	1,395	2,535	3,953	5,297	6,307	3,976	3,471	3,453	2,671	3,243	2,102	1,723
ALTERNATIVE 1												
Wet (28%)	1,951	3,977	4,703	11,855	12,306	7,619	6,709	6,224	3,936	2,927	2,467	2,174
Above Normal (14%)	1,828	1,923	3,839	6,877	7,627	4,767	3,271	3,269	3,526	3,578	1,824	1,775
Below Normal (18%)	1,346	1,329	4,304	3,057	4,750	2,257	2,787	2,889	3,465	3,468	2,227	1,458
Dry (24%)	1,263	2,323	5,064	1,783	4,032	1,775	2,062	2,517	2,628	2,927	1,634	598
Critically Dry (16%)	626	826	1,043	1,055	1,673	1,063	2,146	797	1,713	1,463	1,574	551
Full Simulation Period Average	1,460	2,323	4,039	5,429	6,604	3,803	3,677	3,452	3,124	2,881	1,991	1,351
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	182	-23	-121	209	-1	-24	-49	-21	420	-527	-168	-193
Above Normal (14%)	45	-417	507	338	134	-154	56	69	385	-837	-259	-356
Below Normal (18%)	-121	-607	211	155	436	-476	51	78	867	-876	-33	-155
Dry (24%)	132	123	-60	157	856	-237	-15	165	212	222	-143	-790
Critically Dry (16%)	-20	-425	139	-248	-39	-12	1,284	-368	469	47	79	-316
Full Simulation Period Average	64	-212	87	132	296	-173	205	-1	453	-362	-111	-372

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.4.6 Stanislaus River

Under all the action alternatives, flows in the Stanislaus River result from controlled releases from New Melones Dam and Goodwin Dam, as well as natural accretions. The releases and transfers are determined by a suite of laws, regulations, contracts, and agreements to address demands of water users, requirements for water quality, and needs of fish populations throughout the river and the Delta. In particular, operations of all the action alternatives are regulated by the Water Board's D-1641 decision, which requires flow releases to meet Delta standards and cold water releases to meet temperature targets at compliance points in the lower San Joaquin River; additional water regulation commitments may be incorporated depending on the alternative. Dry hydrologic conditions often lead to inadequate storage in New Melones Reservoir for operators to provide suitable conditions for salmonids and other native species in the lower San Joaquin River. In most cases, however, water temperature rather than flow is the limiting factor creating unsuitable conditions, as discussed below. Flow releases are high during the spring and late October to satisfy downstream demands of water users, Central Valley steelhead protection, and water quality.

Alternative 1 (Water Quality Control Plan) operates the CVP and SWP to D-1641 and tributary specific water right requirements and agreements. Reclamation will operate minimum instream flows under Alternative 1 as shown in Figure 3.3-1 and Table 3.3-2 (EIS, Chapter 3; 1987 Stipulation with CDFW and D-1641, respectively). Alternative 1 does not include specific fall through spring pulse flows.

O.4.6.1 Stanislaus River below Goodwin Dam

CalSim 3 modeling suggest that average monthly flows below Goodwin Dam under Alternative 1 compared to No Action Alternative would generally be higher November, December, February, and June in most water year types (Table O-27). The largest increases under Alternative 1 compared to the No Action Alternative are expected in November of above normal and below normal water year types, and May of dry water year types. The largest decreases under Alternative 1 compared to the No Action Alternative are expected in October of all water year types..

O.4.6.2 Stanislaus River at Mouth

CalSim 3 modeling suggest that average monthly flows at the mouth of the Stanislaus under Alternative 1 compared to the No Action Alternative would generally be higher from February through September, and generally lower from October through November (Table O-28). The largest increases in flow under Alternative 1 are expected in December of an above normal year, in June of wet, above normal, and below normal water year types, and in July of critically dry years. The largest increases in flow are expected in February through March and August through September of dry and critically dry water year types.

Table O-27. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	875	578	752	2,005	2,111	1,887	1,680	1,984	747	288	741	870
Above Normal (14%)	742	200	352	782	1,297	889	1,177	1,134	456	273	287	260
Below Normal (18%)	685	200	462	417	641	382	846	868	335	267	284	280
Dry (24%)	617	200	490	241	230	200	636	563	269	265	283	249
Critically Dry (16%)	591	200	200	217	219	200	529	453	262	268	283	249
Full Simulation Period Average	716	306	494	838	978	802	1,025	1,078	440	273	412	430
ALTERNATIVE 1												
Wet (28%)	592	691	847	1,846	2,302	1,762	1,605	2,013	957	291	677	890
Above Normal (14%)	256	295	453	792	1,239	800	1,135	1,107	597	278	288	269
Below Normal (18%)	251	348	462	429	700	362	1,062	1,088	385	270	284	260
Dry (24%)	193	254	540	268	323	256	873	820	295	266	283	252
Critically Dry (16%)	137	213	213	274	288	234	561	531	259	269	283	249
Full Simulation Period Average	316	393	550	813	1,068	769	1,099	1,196	533	276	394	434
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-283	113	95	-159	190	-125	-75	29	210	4	-63	20
Above Normal (14%)	-485	95	101	10	-58	-89	-41	-27	141	5	1	9
Below Normal (18%)	-434	148	0	12	58	-20	216	220	50	2	0	-21
Dry (24%)	-424	54	50	27	93	56	237	257	26	1	0	3
Critically Dry (16%)	-453	13	13	58	70	34	32	79	-3	1	0	0
Full Simulation Period Average	-400	87	56	-25	89	-32	74	118	93	3	-18	4

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-28. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	844	777	777	1,818	2,241	2,015	1,903	2,079	1,047	549	653	771
Above Normal (14%)	559	413	411	778	1,290	1,052	1,205	1,243	643	377	313	274
Below Normal (18%)	530	396	468	450	676	519	870	984	513	312	293	291
Dry (24%)	474	354	470	330	395	276	601	707	362	235	257	258
Critically Dry (16%)	404	303	245	290	343	210	478	550	252	135	185	191
Full Simulation Period Average	590	482	513	825	1,079	905	1,079	1,191	603	340	370	399
ALTERNATIVE 1												
Wet (28%)	731	758	815	1,698	2,389	2,003	1,863	2,059	1,188	592	645	778
Above Normal (14%)	375	331	487	857	1,365	998	1,270	1,278	793	461	381	335
Below Normal (18%)	354	386	456	472	734	533	1,037	1,230	635	386	335	316
Dry (24%)	316	276	476	352	489	355	828	963	503	336	325	310
Critically Dry (16%)	272	210	203	346	447	311	515	578	341	245	296	306
Full Simulation Period Average	441	429	528	820	1,181	932	1,167	1,300	733	420	420	445
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-114	-19	38	-120	148	-11	-40	-20	141	44	-7	8
Above Normal (14%)	-184	-82	76	79	75	-54	66	35	150	84	68	62
Below Normal (18%)	-175	-10	-12	22	59	15	167	246	122	74	42	24
Dry (24%)	-158	-79	6	22	94	78	227	256	140	101	69	52
Critically Dry (16%)	-132	-92	-42	56	104	101	37	28	89	110	112	115
Full Simulation Period Average	-149	-52	15	-4	102	27	89	110	130	79	49	46

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.4.7 San Joaquin River

Reclamation operates the Friant Division for flood control, M&I and agricultural water supplies, and fish and wildlife purposes. Friant Dam provides flood control on the San Joaquin River, downstream releases to meet senior water rights requirements above Gravelly Ford, Restoration Flows under Title X of Public Law 111-11, and diversions into the Madera and Friant-Kern Canals. The Friant Division facilities include Friant Dam, Millerton Reservoir, and the Friant-Kern and Madera Canals.

Alternative 1 (Water Quality Control Plan) operates the CVP and SWP to D-1641 and tributary specific water right requirements and agreements. In the San Joaquin River, Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision, which is a related action not included in this consultation. There are anticipated changes in San Joaquin River flow below the confluence with the Stanislaus River, because of changes in operations at New Melones reservoir.

O.4.7.1 San Joaquin River at Vernalis

CalSim 3 modeling suggests that average flow in the San Joaquin River at Vernalis under Alternative 1 compared to No Action Alternative are expected to increase December through September, and decrease in October and November throughout the full simulation period (Table O-29). The flows will generally be lower in October and November under Alternative 1 compared to the No Action Alternative. The largest increases under Alternative 1 compared to the No Action Alternative are expected in May of dry and below normal water year types. The largest decreases under Alternative 1 compared to the No Action Alternative are expected in October of all water year types.

Table O-29. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 1 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	2,982	2,957	4,091	9,879	13,068	12,499	12,532	11,481	7,391	3,577	2,375	2,263
Above Normal (14%)	2,222	1,876	2,549	4,210	7,063	6,332	6,587	4,709	3,201	1,899	1,412	1,367
Below Normal (18%)	1,830	1,720	2,722	2,738	4,312	4,104	4,914	3,862	2,439	1,486	1,183	1,215
Dry (24%)	1,542	1,514	2,585	1,992	2,732	2,550	2,992	2,406	1,486	963	925	1,019
Critically Dry (16%)	1,288	1,244	1,499	1,821	2,162	2,038	2,287	1,665	1,129	560	616	738
Full Simulation Period Average	2,061	1,969	2,863	4,618	6,425	6,063	6,399	5,413	3,494	1,856	1,396	1,407
ALTERNATIVE 1												
Wet (28%)	2,883	2,954	4,154	9,785	13,247	12,526	12,545	11,472	7,569	3,652	2,398	2,291
Above Normal (14%)	2,082	1,803	2,633	4,314	7,167	6,293	6,681	4,786	3,395	2,045	1,571	1,517
Below Normal (18%)	1,687	1,725	2,733	2,781	4,401	4,143	5,105	4,141	2,600	1,600	1,292	1,277
Dry (24%)	1,381	1,444	2,604	2,036	2,847	2,651	3,247	2,701	1,671	1,114	1,031	1,082
Critically Dry (16%)	1,164	1,172	1,483	1,891	2,284	2,159	2,343	1,710	1,249	704	756	888
Full Simulation Period Average	1,929	1,930	2,897	4,635	6,553	6,116	6,521	5,549	3,664	1,977	1,492	1,486
ALTERNATIVE 1 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-99	-3	63	-94	179	26	13	-9	178	75	23	28
Above Normal (14%)	-139	-73	84	104	105	-39	94	77	195	146	159	150
Below Normal (18%)	-143	5	11	42	89	39	191	280	161	115	109	62
Dry (24%)	-161	-70	19	44	115	102	255	295	185	151	106	63
Critically Dry (16%)	-124	-72	-17	69	122	122	56	45	121	144	140	150
Full Simulation Period Average	-132	-39	34	18	128	53	122	137	170	121	96	79

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.4.8 Sacramento River Winter-run Chinook Salmon ESU

O.4.8.1 Sacramento River

Spawning and Egg/Alevin Incubation

Winter-run Chinook salmon adults spawn from April through August with peak spawning between May and July (Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). Fry emergence occurs up to 3 months after eggs are spawned, so effects of flow and water temperature on winter-run eggs and alevins may occur from May through November, but primarily occur during June through October.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 1, differences in mean spawning WUA increases in wet and dry water year types and decreases in above normal, below normal, and critically dry water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 1 and the No Action Alternative is a 0.5% increase in wet water years. The largest reduction in estimated spawning habitat is a -1.4% decrease in above normal water year types.

The monthly median value of spawning WUA under Alternative 1 is similar to the No Action Alternative May through August. Spawning WUA median values for all the modeled alternatives are relatively similar in May, June, and August. In July, the median values of spawning WUA are lower across all alternatives when compared to the other months of spawning. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in July than in the other three months (Table O-14). This results in lower spawning WUA results because the winter-run spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 5,000 to 10,000 cfs).

The results of suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for winter-run in the upper Sacramento River may have a minor change to spawning habitat quantities, but that spawning habitat may not be a limiting factor under both the No Action Alternative and Alternative 1 (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). During the months of May through August, winter-run spawning habitat may have a 1.9 to -2.5% difference in spawning habitat across all water year types. July had the highest increase in estimated habitat and June had the lowest decrease in estimated spawning habitat under Alternative 1 when compared to the No Action Alternative.

The two spawning habitat analyses based on CalSim3 simulated flows suggest that Alternative 1 may have a minor (less than 3%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative, and that spawning habitat may not be a limiting factor for winter-run Chinook salmon in the mainstem upper Sacramento River.

SIT Winter-run Lifecycle Model: Spawner Abundance

In the CVPIA winter-run SIT life cycle model, mean winter-run Chinook salmon spawner abundance in the central valley under Alternative 1 is similar to the No Action Alternative, with up 4.5% increase in above normal water year types and a 2.4% decrease in critically dry water year types (Attachment F.2, *CVPIA SIT Winter-run LCM*). For all years, the mean annual spawner abundance was 0.1% lower under Alternative 1 compared to the No Action. Over the full model run period (1980–1999), abundance under Alternative 1 was slightly lower by 1.3% than abundance under the No Action Alternative. Overall, the spawner abundance predicted by the CVPIA winter-run life cycle model is expected to be similar under Alternative 1 to the No Action Alternative, with a slight annual decrease in abundance over all water year types.

IOS: Egg Survival

Under Alternative 1 in critically dry water years, mean predicted winter-run Chinook salmon egg survival is 5.26% lower than when compared to the No Action Alternative (Attachment F.5, *Interactive Object-oriented Simulation Model*). Alternative 1 reflects a change of -0.037 mean proportion predicted to survive when compared to the No Action Alternative. The change in mean predicted winter-run Chinook salmon egg survival in all other water year types less than or equal to ± 0.01. Alternative 1 provides a slightly adverse impact during critically dry water years when compared to the No Action Alternative.

OBAN: Spawner Abundance and Probability of Quasi-Extinction

Alternative 1 compared with the No Action Alternative may have an effect on winter-run Chinook salmon spawner abundance and the probability of quasi-extinction due to differences in flow. These possible differences were evaluated using OBAN. OBAN model results are not accurate predictions of absolute abundance, but instead are predictions of directions of change in the populations. OBAN model results of quasi-extinction represent a proportion of simulations in which the annual abundance is below a quasi-extinction threshold of 100 spawners. The abundance metric was evaluated from the model year 16 to 98 to account for initial model conditions.

Effects on spawner abundance are described by median proportional difference while effects on probability of quasi-extinction are described by the direction of difference compared to the No Action Alternative, not a percent difference. The median proportional difference was calculated due to small No Action Alternative spawner abundances in the denominator affecting this metric. Years with small No Action Alternative abundances are weighted more strongly than years with higher No Action Alternative abundances for the same difference, so the median reduced the influence of these values on the summary metric. For more information refer to Attachment F.6, *Oncorhynchus Bayesian Analysis Model, Addendum*.

Predicted spawner abundance under Alternative 1 was less than under the No Action Alternative (72% less, Table O-30). This decrease under Alternative 1 would have an adverse effect on winter-run Chinook salmon.

Probability of quasi-extinction under Alternative 1 was the same as under the No Action Alternative (0.98, Table O-30). The lack of change under Alternative 1 compared with the No Action Alternative are expected to have no effect on winter-run Chinook salmon.

Table O-30. Summary Metrics by Alternative from the OBAN Model: Spawner Abundance, Probability of Quasi-Extinction, Egg to Fry Survival, and Delta Survival

	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Spawner Abundance	0.74	0.16 (-72%)	1.09 (46%)	1.21 (66%)	1.32 (80%)	1.26 (65%)	0.77 (1%)	0.61 (-14%)
Probability of Quasi-Extinction	0.98	0.98	0.97	0.97	0.97	0.97	0.94	0.98
Egg to Fry Survival	0.137	0.098	0.154	0.165	0.166	0.163	0.102	0.121
Delta Survival	0.879	0.769 (-12.2%)	0.794 (-1.2%)	0.795 (-1.2%)	0.808 (0.5%)	0.811 (0.8%)	1.038 (19%)	0.796 (-1.1%)

Median proportional difference from the No Action Alternative (NAA) is reported for Spawner Abundance and mean proportional difference is reported for Delta Survival.

IOS: Female Escapement

The Interactive Object-Oriented Simulation (IOS) Model is composed of six model stages defined by a specific spatiotemporal context and are arranged sequentially to account for the entire life cycle of winter-run Chinook salmon, from eggs to returning spawners. In sequential order, the IOS Model stages are: spawning, early development, fry rearing, river migration, Delta passage, and ocean survival. In this section, female escapement is discussed.

Under Alternative 1 in all water year types, mean annual predicted female escapement of winter-run Chinook salmon is 11.84-15.05% lower than when compared to the No Action Alternative (Attachment F.5, *Interactive Object-oriented Simulation Model*). The change in mean annual predicted female escapement of in all water year types ranging from -309 to -525 individuals. Alternative 1 provides an adverse impact to mean annual predicted female escapement of winter-run Chinook salmon when compared to the No Action Alternative.

OBAN: Egg to Fry Survival

Alternative 1 compared with the No Action Alternative may have an effect on winter-run Chinook salmon egg to fry survival due to differences in flows and temperature. These possible differences were evaluated using OBAN. Results are presented as median difference across 1,000 annual simulations. Effects are described by the direction of difference compared to the No Action Alternative, not a percent difference. Several years had extremely low survivals (i.e., < 5e-05).

Egg to fry survival under Alternative 1 was less than under the No Action Alternative (-0.036 difference, Table O-30). This decrease under Alternative 1 would have an adverse effect on winter-run Chinook salmon.

Redd Dewatering Analysis

Alternative 1 shows minor increases in redd dewatering potential from wet to dry years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). During winter and spring, the principal incubation periods for the other Chinook salmon races and steelhead, redd dewatering is generally higher during wet water years because periodic storms and high runoff, which increase flow fluctuations, tend to be more frequent in such water years. However, winter-run spawning and incubation occur during late spring through early fall, when flows tend to be less variable. The low percentages of winter-run Chinook salmon redd dewatering in wet years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*) may result from increased stability in project operations related to greater reservoir storage levels. The largest difference between the No Action Alternative and Alternative 1 is a 31.9% increase for critically dry water years and the largest reduction is 12.2% for below normal water years. It is important to note that these estimates represent, respectively, 4.5% and 2.4% absolute differences in the percentages of redds dewatered, instead of total percentage of the population redds dewatered.

Overall, the results indicate that redd dewatering potential under Alternative 1 would be substantially higher, as estimated using the relative (percent) change, than under the No Action Alternative, especially during critically dry and above normal water years. However, in terms of absolute change the differences are modest.

Temperature Dependent Mortality (TDM)

Differences in monthly temperatures on the upper Sacramento River under Alternative 1 compared with the No Action Alternative may have effects on water-temperature-related mortality of winter-run Chinook salmon eggs and alevins. These possible differences were evaluated using several quantitative temperature-dependent models (TDM), hereinafter referred to as the Martin and Anderson models.

Both Martin and Anderson models are responsive to modeled Sacramento River temperatures at Keswick Dam, at the confluence with Clear Creek, and at Bend Bridge. The modeling was based on HEC-5Q water temperature estimates for the years used in the HEC-5Q modeling (1922–2021).

Under Alternative 1 for the Anderson model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.239, 0.811, and 0.039 (all greater than the No Action Alternative, up to 1200% greater in a wet water year type). Expected proportional TDM values for the Anderson model were greater under Alternative 1 than No Action Alternative for all water year types.

Under Alternative 1 for the Martin model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.216, 0.747, and 0.047 (all greater than the No Action Alternative, up to 193.8% greater in a wet water year type). Expected proportional TDM values for the Martin model were greater under Alternative 1 than No Action Alternative in all water year types except above normal (0% less).

Relative to the Anderson model, expected proportional TDM values were lower for the Martin model across all water year types combined and for all water year types except above normal (model predictions were equal) and wet (Martin predictions were greater than Anderson predictions). For the Anderson and Martin models, Alternative 1 produced greater TDM for a greater fraction of all modeled water year types (Attachment L.2, *Egg-to-fry Survival and Temperature Dependent Mortality*). An increase in TDM under Alternative 1 compared with the No Action Alternative would have an adverse effect on incubating winter-run Chinook salmon eggs.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 16 for Keswick Dam and Table 18 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 20 for Keswick Dam and Table 22 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during May through November are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 24 for Keswick Dam and Table 26 for below Clear Creek.

Results for the three analyses are summarized in Table O-31. Table O-31, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%. If the exceedance or occurrence value was >10% lower under the alternative relative to the No Action Alternative, the result is termed "Favorable". If the exceedance or occurrence value was >10% higher under the alternative relative to the No Action Alternative, the result is termed "Unfavorable". The 10% value was chosen to represent a level of difference between the alternative and the No Action Alternative that could have a biologically meaningful effect on the species but considers the coarse definition in the data (e.g., a difference in just one of the 14 above normal water years represents a 7% difference). This value should not be interpreted as a significance threshold.

Under Alternative 1, there were no month-water year type combinations (0% of total combinations during the period) with unfavorable results (Table O-31). There were no combinations (0%) with favorable results for the 59.9°F pathogen virulence threshold, but there were between two and eight month-water year combinations (6.7% and 22.9%) with favorable results, depending on location and index range, for the 42.1°F to 55°F range for spawning initiation and 42.8°F to 56°F range for egg incubation and fry emergence. These results suggest that there would be positive biologically meaningful temperature-related effects of Alternative 1 on winter-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

Table O-31. Summary of Results for Water Temperature Analyses for Winter-run Chinook Salmon Spawning and Egg/Alevin Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Below Keswick Dam							
Favorable	8 (22.9%)	5 (14.3%)	5 (14.3%)	5 (14.3%)	5 (14.3%)	8 (22.9%)	3 (8.6%)
Unfavorable	0 (0.0%)	1 (2.9%)	1 (2.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Below Clear Creek							
Favorable	8 (22.9%)	9 (25.7%)	10 (28.6%)	9 (25.7%)	10 (28.6%)	11 (31.4%)	5 (14.3%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	1 (2.9%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Below Clear Creek							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
42.8°F–56°F RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Below Keswick Dam							
Favorable	2 (5.7%)	2 (5.7%)	4 (11.4%)	2 (5.7%)	2 (5.7%)	4 (11.4%)	4 (11.4%)
Unfavorable	0 (0.0%)	2 (5.7%)	1 (2.9%)	3 (8.6%)	2 (5.7%)	1 (2.9%)	0 (0.0%)
Below Clear Creek							
Favorable	5 (14.3%)	5 (14.3%)	6 (17.1%)	5 (14.3%)	5 (14.3%)	6 (17.1%)	6 (17.1%)
Unfavorable	0 (0.0%)	3 (8.6%)	2 (5.7%)	3 (8.6%)	2 (5.7%)	1 (2.9%)	1 (2.9%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action is expected to have possible minor beneficial to minor adverse impacts on spawning and redd dewatering habitat, possible substantial adverse impacts on spawner abundance and female escapement, and no impact on the probability of quasi-extinction due to differences in flow. Alternative 1 relative to the No Action is expected to have possible adverse impacts using four secondary biological models: IOS, Anderson and Martin (TDM), and OBAN. Alternative 1 relative to the No Action Alternative using a coarser analysis is expected to have possible beneficial impacts on spawning and egg/alevin incubation due to differences in water temperature.

Juvenile Rearing and Emigration

Winter-run Chinook salmon juveniles rear in the Sacramento River primarily from late summer to late winter and emigrate from the river to the Delta beginning in November (see Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). The proportion of juveniles surviving to emigrate to the Delta depends largely on habitat conditions, including flow and water temperature. Inundated floodplain habitat has been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001a, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 1, mean fry rearing weighted usable area (WUA) increases in wet and above normal water year types and decreases in below normal, dry and critically dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 3.2% increase in above normal water years. The largest reduction in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 1.5 % decrease in critically dry water year types.

The monthly median value of fry rearing WUA under Alternative 1 is similar to the No Action Alternative throughout the fry rearing period of August through December (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Fry rearing WUA median values for all the modeled alternatives are relatively similar September through December but slightly lower in August. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in August in comparison to the other fry rearing months, with an average flow of 9,332 cfs under Alternative 1 (Table O-14). Segment 5, which has the highest distribution of winter-run spawning, has decreased WUA values when flows are between 5,000 and 10,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), leading to lower WUA values during higher flows in August. Winter-run fry rearing WUA starts to increase at flows above 10,000 cfs, and peak at flows around 30,000 cfs. These peak rearing flows are not expected to occur under the No Action Alternative or Alternative 1 during the fry rearing period in the Sacramento River below Keswick Dam. Winter-run is the only Sacramento River salmonid race or species that shows this pattern.

Winter-run Chinook salmon fry rearing habitat analysis results suggest that Alternative 1 may have a minor (less than 3.5%) increase and/or decrease in estimated fry rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the upper Sacramento River.

Juvenile Rearing Habitat Analyses

Under Alternative 1, mean juvenile rearing WUA increases in wet, above normal, and dry water year types and decreases in below normal and critically dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 0.5% increase in above normal water years. The largest reduction in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 0.1 % decrease in below normal water year types.

The monthly median value of juvenile rearing WUA under Alternative 1 is similar to the No Action Alternative October through January. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are higher in January compared to the other months of juvenile rearing (Table O-14). Segment 5 has decreased WUA values when flows are between 5,000 and 10,000 cfs but the WUA values do not change as drastically with juvenile rearing in comparison to fry rearing (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Winter-run juvenile rearing WUA values start increasing at flows above 15,000 cfs, and peak at flows around 30,000 cfs. These peak rearing flows are not expected to occur under the No Action Alternative or Alternative 1 during the juvenile rearing period in the Sacramento River below Keswick Dam. Winter-run is the only Sacramento River salmonid race or species that shows this pattern.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for winter-run in the upper Sacramento River had a 2.3% to -0.9% difference between the months of October through January (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in November and the greatest reduction in estimated habitat may occur in January under Alternative 1 in comparison to the No Action Alternative.

The results of the two juvenile winter-run Chinook salmon rearing habitat analyses suggest that Alternative 1 may have a negligible (less than 1%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the upper Sacramento River.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles who primarily are stronger swimmers. Alternative 1 shows a substantial reduction in stranding of winter-run juveniles from critically dry to wet water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*) and an increase from July to October (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Winter-run fry rearing occurs primarily during summer through early fall, when flows tend to be less variable. The minimum rates of stranding for winter-run fry during wet years may result from increased stability in project operations related to greater reservoir storage levels.

Alternative 1 has lower juvenile stranding of winter-run Chinook salmon fry than the No Action Alternative in all water year types except dry water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The differences in mean stranding range from 7.8% lower stranding for Alternative 1 in below normal water year types to 3.2% higher in dry water years.

Overall, winter-run Chinook salmon juvenile stranding for fry is lower or little different under Alternative 1 in comparison to the No Action Alternative.

Survival and Travel Time: XT and Flow Survival Threshold Models

Del Rosario et al. (2013) found that ≥5% catch at the Knights Landing Rotary Screw Trap (RST) coincided with first day of flow of at least ~14,100 cfs (400 cm) at Wilkins Slough. Acoustically tagged fish released at locations in the upper Sacramento River under varying hydrological conditions are used to estimate survival probabilities and travel times rates. As fish migrate downstream towards the Delta, individuals encounter a range of environmental conditions and transition from reaches with unidirectional flow (upstream) to reaches with bidirectional flow (tidally driven, downstream). Outmigrating juveniles may be exposed to predation and as inflow declines and tidal influence moves upstream, travel time and distance may increase leading to higher exposure to predators. Michel et al. (2021) identified an optimal flow threshold condition favorable for outmigration for juvenile Chinook salmon, 10,712 cfs, which could provide an additional 2.7-fold increase in survival. Travel and survival rates of Chinook salmon in upper Sacramento River reaches are strongly correlated (Notch et al. 2020). Authors hypothesize one mechanism for the threshold is faster outmigration rates due to higher flows decrease exposure to possible predation (Michel et al. 2021).

Differences in daily flows (Upper Sacramento River Daily Operations Model, USRDOM) under Alternative 1 compared with the No Action Alternative may have effects on juvenile Chinook salmon's travel time and survival probabilities in the Upper Sacramento River. These possible differences were evaluated using several quantitative models: XT and Flow Survival Threshold.

Mean daily Sacramento River flows at Keswick Dam and mean daily Sacramento River flows below Wilkins Slough (March 15th to June 15th) are equal to or greater under Alternative 1 compared with the No Action Alternative (Attachment J.4, *XT Model*; Attachment J.5, *Flow Threshold Salmon Survival Model*). These two quantitative models provide results that demonstrate the flows under Alternative 1 compared with the No Action Alternative could increase survival and decrease travel time for outmigrating juvenile Chinook salmon on the Sacramento River limiting juveniles' exposure to predation and poor environmental conditions.

Annual mean survival probability under Alternative 1 was greater than annual mean survival probability under the No Action Alternative in all water year types (5% greater in wet water year types to up to 64% greater in critically dry water year types). This increase, particularly in dry and critically dry water year types of up to 64%, would have a substantial beneficial effect on outmigrating juvenile Chinook salmon. Under both scenarios, average annual mean survival probability was highest during the wet water year types and decreased as the water year type became drier (Attachment J.5, *Flow Threshold Salmon Survival Model*).

Mean survival probability for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the Delta Cross Channel (DCC) on the Sacramento River under Alternative 1 was equal to or greater than mean survival probability under the No Action Alternative (equal in wet and above normal water year types to up to 2% greater in dry and critically dry water year types). This increase of up to 2% would have a minimal effect on outmigrating juvenile Chinook salmon. (Attachment J.4, *XT Model*).

Mean travel time (days) for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 1 was equal to mean travel time under the No Action Alternative in a wet water year type or less than mean travel time under the No Action Alternative (up to 8% less in all other water year types to the confluence of the American and Sacramento rivers and in all water year types to the DCC). This decrease of up to 8% may have a large beneficial effect on outmigrating juvenile Chinook salmon, particularly dependent on predator presence and environmental conditions (e.g., water temperature) (Attachment J.4, *XT Model*).

<u>Winter-run Juvenile Production Index (JPI)</u>

For this effects analysis, the JPI model was run for years 2002-2022 when data on female spawners was available. Temperature data at node (BLW KESWICK) from the HEC-5Q model was used to represent the CDEC station SAC (Sacramento River at Highway 44). Flow data from CalSim 3 node (C_SAC257) was used to represent CEDC station BND (Sacramento River at Bend Bridge). The output of the model is the predicted JPI for each year. Full results of the analysis can be found in Attachment L.3, *Winter-run Chinook Salmon Juvenile Production Index Model*.

Under Alternative 1, the mean predicted JPI is generally higher than No Action Alternative, ranging from 45.23% higher in 2014 to 8.31% lower in 2003. Fourteen of the years analyzed (2002-2021) resulted in higher JPI under Alternative 1 when compared to the No Action Alternative and lower JPI in four of the years when compared to the No Action Alternative. These results suggest that in most years the benefits to juvenile winter-run Chinook salmon under Alternative 1 can be substantial and in a smaller number of years the effects are adverse when compared to the No Action Alternative. Overall, Alternative 1 is expected to have a positive effect on the number of juveniles produced annually when compared to the No Action Alternative.

IOS: Fry Survival and Juvenile River Migration Survival

Under Alternative 1, in critically dry water years, mean predicted winter-run Chinook salmon fry survival is 6.35% lower than when compared to the No Action Alternative (Attachment F.5, *Interactive Object-oriented Simulation Model*). However, the change in mean predicted winter-run Chinook salmon fry survival in all water year types less than or equal to ± 0.04. There is not a substantial difference in predicted survival of winter-run Chinook salmon fry between Alternative 1 and the No Action Alternative.

Under Alternative 1 in all water years, mean predicted river migration survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative (Attachment F.5, *Interactive Object-oriented Simulation Model*). However, the change in mean predicted river migration survival in all water year types less than or equal to 0.002. There is not a substantial difference in predicted river migration survival of winter-run Chinook salmon juveniles between Alternative 1 and the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 28 for Keswick Dam, Table 30 for Red Bluff Diversion Dam, and Table 32 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 34 for Keswick Dam, Table 36 for Red Bluff Diversion Dam, and Table 38 for Hamilton City.

Results for the two analyses are summarized in Table O-32. Table O-32, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 55.4°F to 68°F optimum temperature range analysis, there were two and five month-water year type combinations (6.7% to 16.7% of total combinations during the period) with favorable results, depending on location, no combinations (0%) with unfavorable results at Keswick Dam and Hamilton City, and two combinations (6.7%) with unfavorable results at Red Bluff Diversion Dam (Table O-32). For the 75.2°F upper incipient lethal temperature under Alternative 1, there would be no favorable or unfavorable results (0%) at any location. These results suggest that there would be positive water temperature-related effects of Alternative 1 on winter-run Chinook salmon juvenile rearing and outmigration in the Sacramento River.

Table O-32. Summary of Results for Water Temperature Analyses for Winter-run Chinook Salmon Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Below Keswick Dam							
Favorable	2 (6.7%)	2 (6.7%)	2 (6.7%)	4 (13.3%)	2 (6.7%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	2 (6.7%)	0 (0.0%)	0 (0.0%)	2 (6.7%)	3 (10.0%)
Red Bluff Diversion Dam							
Favorable	5 (16.7%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (6.7%)	2 (6.7%)	1 (3.3%)	1 (3.3%)	3 (10.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	4 (13.3%)	1 (3.3%)	2 (6.7%)	1 (3.3%)	1 (3.3%)	3 (10.0%)	2 (6.7%)
Unfavorable	0 (0.0%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	0 (0.0%)	1 (3.3%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have possible minor beneficial to minor adverse impacts on fry and juvenile rearing habitat, a slightly beneficial impact to no impact on behavior (fry stranding, juvenile production index), and a minimal impact on fry survival except in critically dry years where there may be an adverse impact due to differences in flow. Alternative 1 relative to the No Action Alternative could have a substantial beneficial impact, depending on water year type, on individuals' survival and travel time in the upper Sacramento River due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have a beneficial impact on juvenile rearing and emigration due to differences in water temperature.

Adult Upstream Migration and Holding

Winter-run Chinook salmon adults enter the Sacramento River from the Delta and make their way to the upper Sacramento River, beginning as early as December through late spring (May/June) (see Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). They hold in the upper River within 10 to 15 miles of Keswick Dam until they are ready to spawn, which may extend through August (Windell et al. 2017). Most of the run passes Red Bluff Diversion Dam from January to May with the peak in mid-March (Hallock and Fisher 1985).

Potential changes to winter-run Chinook salmon from seasonal operations

CalSim 3 Flows

Releases from Shasta Reservoir during November through early May may be reduced to conserve water for the May through October winter-run Chinook salmon and spring-run Chinook salmon spawning and incubation periods, resulting in reduced flow in the middle Sacramento River. Lower flow in the Sacramento River relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of winter-run adults into canals and behind weirs, increasing their stranding risk. Once the adults have migrated upstream on the Sacramento River, they reach holding habitat in the upper Sacramento River. In the upper Sacramento River, they are more directly affected by Shasta Reservoir and Keswick Dam operations designed to preserve cold water for the winter-run Chinook salmon and spring-run Chinook salmon spawning and incubation periods.

During the December through May/June period of adult winter-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 1 at Sacramento River below Keswick Dam, below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough would generally be similar to or greater than flows under the No Action Alternative, except during February of a critically dry water year type below Keswick Dam when flows would be up to 6% less. Flows under Alternative 1 in December of an above normal water year type would be more than 5% greater than flows under the No Action Alternative at all four locations, up to 28% greater at Sacramento River below Keswick Dam. Flows under Alternative 1 in April of a critically dry water year type would be more than 5% greater than flows under the No Action Alternative at all four locations, up to 15% greater at Red Bluff Diversion Dam. Flows at Hamilton City and Wilkins Slough under Alternative 1 would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 1 between December and May/June would be greater than 5,500 cfs at Wilkins Slough and greater than 7,500 cfs at Hamilton City (Table O-14 through Table O-17).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range for winter-run Chinook salmon adult migration and holding are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 4 for Keswick Dam, Table 6 for Red Bluff Diversion Dam, and Table 8 for Hamilton City.

Results are summarized in Table O-33. Table O-33, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Table O-33 indicates, that under Alternative 1, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at all locations. Differences between Alternative 1 and the No Action Alternative in the frequency of occurrence of water temperature outside the 37.9°F to 68°F range were within 10% for each month-water year type combination. These results suggest that there would be negligible effects of Alternative 1 on water temperature conditions for winter-run Chinook salmon adult migrants in the Sacramento River.

Table O-33. Summary of Results for Water Temperature Analyses for Winter-run Chinook Salmon Adult Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL ADULT MIGRATION RANGE							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	1 (3.3%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have no impact to a beneficial impact due to differences in flow, depending on location and month, on upstream migrating and holding adult winter-run Chinook salmon, average monthly flows at Hamilton City and Wilkins Slough are high enough to allow upstream passage. Alternative 1 relative to the No Action Alternative is expected to have a negligible impact on upstream migrating and holding adult winter-run Chinook salmon due to differences in water temperature.

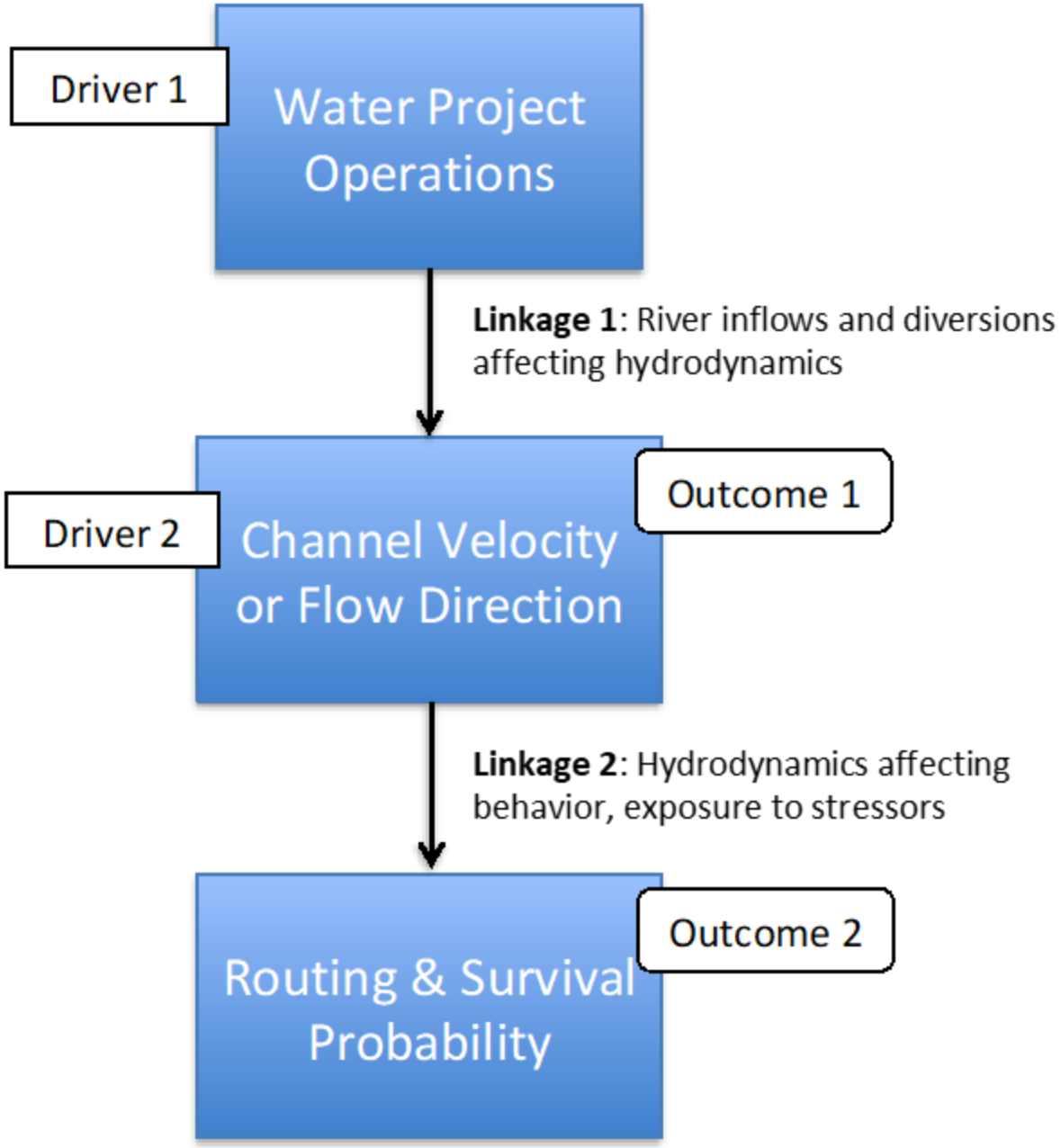
O.4.8.2 Bay-Delta

Juvenile Rearing and Emigration

Rearing winter-run Chinook salmon are present in the Delta from October to May (see Section O.1.9.1.1, *Winter-run Chinook Salmon, Sacramento River ESU*). Key habitat attributes relevant to seasonal operations in the Delta include out-migration cues and entrainment risk. Juveniles enter the Delta primarily during December through April and most emigrate past Chipps Island by the end of April but can potentially exit as late as May (Brandes and McLain 2001; del Rosario et al. 2013). A critical assumption in these analyses is LAD criteria used to identify juveniles (vs genetic ID) are sufficient to represent juveniles' downstream migration patterns.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to adversely affect juvenile Chinook salmon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, and 2) "far-field" mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team's (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver-linkage-outcome (DLO) framework for specifying how water project operations (the "driver") can influence juvenile salmonid behavior (the "linkage") and potentially cause changes in survival or routing (the "outcome"). The SST concluded altered "Channel Velocity" and altered "Flow Direction" were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O-14 provides a simplified conceptual model of the DLO defined by the CAMT SST.



This conceptual model is a simplified version of the information provided by the CAMT SST.

Figure O-14. Conceptual Model for Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta

Differences in hydrology in the Delta under Alternative 1 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using several quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions.

Zone of Influence

Zone of influence analysis is used to evaluate the spatial extent of influence of exports under CVP and SWP diversions using DSM2-Hydro velocity results. There may be differences in the spatial extent of export influence under Alternative 1 compared with the No Action Alternative during the OMR Management period (between December and June). To represent conditions in the Delta, results are binned and presented using OMR groupings (< -5,500; -5,000; -3,500; and -2,000) for specific locations (Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River). The proportion of overlap from probability density curves of hourly average velocity with and without pumping for each modeled scenario were analyzed for the alternative and the No Action Alternative. Differences in the spatial extent of export influence between Alternative 1 and the No Action Alternative by OMR bins are presented as a direction, not a percent difference. For a detailed explanation of methods and analyses, see Attachment I.3, *Delta Export Zone of Influence Analysis*.

The proportional overlap of Alternative 1 (pumping vs no pumping) was less than proportional overlap of the No Action Alternative (pumping vs no pumping) at Turner Cut under all OMR bins except -3,500 (Attachment I.3, *Delta Export Zone of Influence Analysis*). The proportional overlap of Alternative 1 (pumping vs no pumping) ranged from greater than to less than proportional overlap of the No Action Alternative (pumping vs no pumping) at the San Joaquin River at Jersey Point under all OMR bins. The proportional overlap of Alternative 1 (pumping vs no pumping) was less than proportional overlap of the No Action Alternative (pumping vs no pumping) at Old River at Middle River under the greatest and least OMR bins (-2,000 and < -5,500).

With incremental decreases in OMR under Alternative 1 and the No Action Alternative, proportional overlap at these three locations decreases, with more subtle changes along the San Joaquin River at Jersey Point compared to Turner Cut and Old River at Middle River. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping.

Flow into Junctions

For the present analysis of flow routing into junctions was based on the proportion of flow entering a junction away from the main stem, from DSM2-HYDRO outputs. Fifteen-minute data were used to calculate the daily proportion of flow that enters the junction, following the methods of Cavallo et al. (2015). The daily value calculated from the 15-minute data will be used to calculate summary statistics (box plots) for each month (December–June) and water year-type. Assumptions and uncertainties that apply to the DSM2 model would also apply to this analysis. This model does not directly predict routing of fish into these junctions although there is a model available to accomplish this (Cavallo et al. 2015). If the results of this analysis are used to infer

fish movement, additional uncertainties are introduced. Flow routing is averaged over 24 hr. However, flow routing can change significantly within that period, particularly at junctions where tidal water movement dominates. Thus, fish arriving at a junction may experience very different instantaneous flow routing depending on their time of arrival. To link these data frames with fish movement requires the assumption that fish arrive at the junction uniformly over the 24-hour averaging period. Additionally, it must be assumed that the behavior of fish at junctions is the same over the range of hydrologic conditions modeled (e.g. the relationship is linear across the range of data).

The following section covers discussion of the Central Valley Project and Head of Old River junctions. An expanded set of junction analysis results can be found in Attachment I.10, *Flow into Junctions*.

Under Alternative 1 in all OMR bins except <-5,500, proportion of flow entering the Central Valley Project (CVP) is less than the No Action Alternative. Changes in proportion of flow entering the CVP when OMR was <-5,500 and -3,500 was 0.0307 and -0.022, respectively, indicating a negligible difference from the No Action Alternative. However, when OMR was -2,000 and -5,000 the change in predicted proportion of flow into CVP was -0.0596 and -0.0521, indicating that slightly less flow will be routed into CVP under Alternative 1 than when compared to the No Action Alternative.

Under Alternative 1 in all OMR bins, predicted proportion of flow entering the Head of Old River (HOR) is less than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than -0.0453, indicating a negligible difference between Alternative 1 and the No Action Alternative.

<u>Summary</u>

Alternative 1 relative to the No Action Alternative is expected to influence flow into the Head of Old River and CVP junctions. Under Alternative 1, possibly less flow into CVP under OMR -2,000 and -5,000; possibly less flow into HOR under all OMR groups. Impacts of pumping under both Alternative 1 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and, thus, more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Winter-run Chinook Salmon

Zeug and Cavallo (2014) analyzed more than 1,000 release groups representing more than 28 million coded wire tagged juvenile fish including winter-run, late fall–run and fall-run Chinook salmon. This data represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Cavallo (2016) provided a supplemental assessment of winter-run Chinook salmon entrainment risk (building upon Zeug and Cavallo 2014) that showed total CVP and SWP exports described entrainment risk better than OMR or other flow metrics. Entrainment loss results as reported below represents the proportion of coded wire tagged winter-run Chinook salmon released upstream of the Delta which were entrained at South Delta export facilities. This proportion accounts for and includes expansion for sampling effort at the salvage facilities and also prescreen mortality. With total exports of ≤ 6,500 cfs, entrainment loss rates for winter-run Chinook salmon range from 0 to 1.5% (mean 0.1%) (Zeug and Cavallo 2014). With total exports

greater than 6,500 cfs, entrainment losses range from 0 to 4% (mean 0.25%) (Zeug and Cavallo 2014).

Differences in monthly flows on the Sacramento River under Alternative 1 compared with the No Action Alternative may have impacts on entrainment probability of juvenile Chinook salmon. These possible differences were evaluated using three quantitative models: (1) salvage density; (2) the Negative Binomial model; and (3) Coded Wire Tag Salvage.

Salvage Density and Negative Binomial

Predictions from the salvage density model for genetic and length at date (LAD) winter-run Chinook salmon include mean monthly total exports. Predictions from the negative binomial loss model for LAD winter-run Chinook salmon include mean monthly total exports and mean monthly San Joaquin River flows at Vernalis. Table O-19 shows modeled mean monthly total exports at SWP and CVP and Table O-29 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of LAD winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types under Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 94% greater in a below normal water year type (Table O-34). Predicted average monthly loss of LAD winter-run Chinook salmon at CVP Jones Pumping Plant for all the months of December through April under Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 15% greater in a below normal water year type (Table O-35). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly loss of genetic winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 93% greater in a below normal water year type (Table O-36). Predicted average monthly loss of genetic winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 15% greater, in all water year types except critically dry, where Alternative 1 was up to 12% less than the No Action Alternative (Table O-37). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Table O-34. Predicted Average Monthly Loss of Length-at-Date Winter-run Chinook Salmon at Banks by Water Year Type for all Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	404	548 (36%)	422 (-23%)	424 (0%)	415 (-2%)	414 (0%)	185 (-55%)	434 (135%)	6: Dec–May
Above Normal	266	501 (88%)	271 (2%)	268 (1%)	242 (-9%)	242 (-9%)	214 (-20%)	278 (4%)	6: Dec–May
Below Normal	300	584 (94%)	303 (1%)	294 (-2%)	256 (-15%)	260 (-13%)	271 (-10%)	316 (5%)	6: Dec–May
Dry	140	249 (77%)	136 (-3%)	136 (-3%)	118 (-16%)	120 (-14%)	158 (13%)	142 (1%)	6: Dec–May
Critically Dry	15	19 (25%)	15 (2%)	13 (-12%)	13 (-11%)	14 (-9%)	16 (8%)	16 (8%)	5: Dec–Apr

Table O-35. Predicted Average Monthly Loss of Length-at-Date Winter-run Chinook Salmon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	52	54 (3%)	54 (4%)	54 (3%)	53 (1%)	53 (2%)	40 (-23%)	55 (6%)	5: Dec–Apr
Above Normal	52	58 (11%)	55 (5%)	55 (5%)	48 (-8%)	48 (-8%)	38 (-27%)	56 (7%)	5: Dec–Apr
Below Normal	117	135 (15%)	116 (-1%)	118 (1%)	98 (-16%)	97 (-17%)	67 (-42%)	119 (1%)	5: Dec–Apr
Dry	45	51 (12%)	44 (-3%)	44 (-3%)	39 (-14%)	39 (-13%)	23 (-49%)	45 (-1%)	5: Dec–Apr
Critically Dry	9	9 (2%)	9 (-7%)	9 (-8%)	8 (-9%)	8 (-9%)	4 (-60%)	9 (-1%)	5: Dec–Apr

Table O-36. Predicted Average Monthly Loss of Genetic Winter-run Chinook Salmon at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	138	179 (30%)	146 (6%)	146 (6%)	143 (4%)	142 (3%)	59 (-57%)	152 (10%)	6: Dec–May
Above Normal	86	163 (89%)	89 (3%)	88 (2%)	77 (-10%)	77 (-10%)	72 (-16%)	93 (8%)	6: Dec–May
Below Normal	92	178 (93%)	92 (0%)	88 (-5%)	71 (-23%)	73 (-21%)	82 (-11%)	94 (2%)	6: Dec–May
Dry	17	31 (79%)	17 (0%)	17 (0%)	14 (-19%)	14 (-16%)	22 (26%)	18 (4%)	6: Dec–May
Critically Dry	2	2 (22%)	2 (10%)	2 (-2%)	2 (-2%)	2 (2%)	2 (8%)	2 (17%)	5: Dec–Apr

Table O-37. Predicted Average Monthly Loss of Genetic Winter-run Chinook Salmon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	17	17 (2%)	18 (6%)	17 (5%)	17 (2%)	17 (3%)	12 (-25%)	18 (10%)	5: Dec–Apr
Above Normal	17	19 (10%)	18 (6%)	18 (5%)	15 (-13%)	15 (-13%)	14 (-22%)	19 (9%)	5: Dec–Apr
Below Normal	34	39 (15%)	34 (-1%)	35 (3%)	26 (-24%)	25 (-26%)	22 (-36%)	35 (2%)	4: Dec, Feb–Apr
Dry	22	25 (10%)	22 (-1%)	22 (-1%)	18 (-20%)	17 (-22%)	13 (-43%)	22 (-1%)	2: Jan, Mar
Critically Dry	6	5 (-12%)	5 (-8%)	5 (-15%)	5 (-19%)	5 (-20%)	2 (-68%)	6 (-3%)	2: Jan, Mar

Predicted average monthly salvage of LAD winter-run Chinook salmon at the Delta fish collection facilities for the months of December through April under Alternative 1 was greater than predicted average monthly salvage under the No Action Alternative, up to 267% greater in an above normal water year type (Table O-38). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*).

Table O-38. Predicted Average Monthly Salvage of Juvenile Winter-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type, December–April

Water Year Type	NAA	Alt1	Alt2w TUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	13	25 (99%)	15 (20%)	15 (20%)	14 (13%)	14 (11%)	6 (-53%)	16 (28%)
Above Normal	8	28 (267%)	9 (13%)	8 (11%)	6 (-16%)	6 (-17%)	8 (4%)	9 (22%)
Below Normal	6	22 (251%)	6 (1%)	6 (1%)	5 (-25%)	5 (-25%)	6 (-11%)	7 (3%)
Dry	5	16 (224%)	5 (-6%)	5 (-6%)	4 (-23%)	4 (-23%)	4 (-14%)	5 (4%)
Critically Dry	4	7 (88%)	3 (-8%)	3 (-14%)	3 (-17%)	3 (-17%)	2 (-40%)	4 (6%)

Winter-run Chinook Salmon Coded Wire Tag Salvage Model

The Winter-run Chinook Salmon Coded Wire Tag (CWT) Proportional Salvage Model was developed to estimate the fraction of juvenile winter-run Chinook salmon in the Delta predicted to be salvaged based on hydrologic conditions and fish size. To apply this model to hydrologic scenarios outside of those used to construct the model, a fixed number of winter-run Chinook salmon entering the Delta each month was used. The raw output of the model is the number of fish salvaged. However, an offset variable was used to convert this number to a proportion. In this way, the model predicts the magnitude of salvage independent of the number of fish that may actually be in the Delta during a given month.

Predicted mean of annual proportion of winter-run Chinook salmon salvaged at CVP and SWP for all months October through May under Alternative 1 was consistently greater than under the No Action Alternative in all water year types, up to 182% greater in above normal years (Attachment I.9,, *Winter-run Chinook Salmon Coded Wire Tag Salvage Model*). Although the percentage difference between scenarios was great, all predicted proportion salvaged are less than ± 0.01.

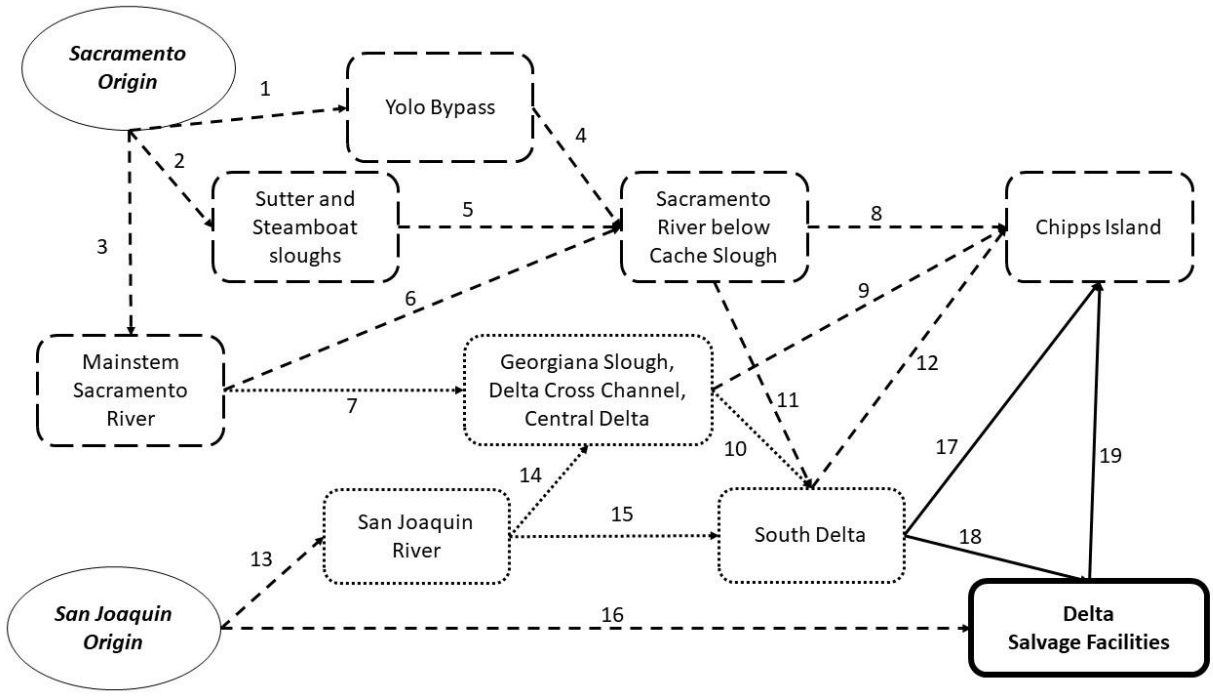
When looking at predicted salvage proportion of winter-run Chinook salmon by water year type and month, Alternative 1 was consistently higher in all months except November of critically dry and dry years. Overall, Alternative 1 is expected to increase the number of fish salvage when compared to the No Action Alternative, however no difference was more than ± 0.01 predicted proportion salvaged.

Summary

Alternative 1 relative to the No Action Alternative is expected to have a potential adverse impact on the entrainment of genetically and LAD identified juvenile winter-run Chinook salmon in the Delta at both fish facilities due to differences in flow, supported by results from two quantitative models. However, a third model suggests no impact between Alternative 1 and the No Action Alternative on predicted salvage proportion of juvenile winter-run Chinook salmon due to differences in flow.

Potential changes to routing of winter-run Chinook salmon

Winter-run Chinook salmon travel through different migratory pathways. Using a conceptual model, a single fish in any location could have arrived at that location via one of several pathways (Figure O-15). For example, a fish observed salvage could have arrived via one of many pathways (e.g., Sacramento Origin via the mainstem Sacramento then below Cache Slough, then South Delta or via the DCC and Central Delta then the South Delta). If a proportion of fish is higher down a migratory pathway documented as a route with higher survival rates for juvenile salmonids, then fish migrating through that route will likely have a better chance of surviving to the ocean than fish migrating through a sub-optimal route (e.g., experiencing potential entrainment into the Central Delta through the DCC or Georgiana Slough).



Higher survival symbolized by heavy dashed lines and boxes, medium to lower survival symbolized by thinner dotted lines and boxes, origin noted by ovals, and the Delta Salvage facilities symbolized by a heavy solid line and box.

Figure O-15. Conceptual Model of Delta Regions and Winter-run Chinook Salmon Routing Symbolized by Fish Fate

Empirical estimates of acoustically tagged late fall-run Chinook salmon from Coleman National Fish Hatchery (CNFH) tracked in December 2006, January and December 2007, and January 2008 experienced routing in the mainstem Sacramento from 35.2% to 49.8%, through Georgiana Slough 0% to 31.1%, and through the Sutter and Steamboat sloughs 19.8% to 41.4% (Perry 2010). Results suggest the proportion of fish entering each route generally follows river flow but is not always in agreement with the proportion of discharge entering that route, suggesting another parameter may affect fish routing. Release groups experienced different discharge and export conditions leading to wide ranges in routing probabilities. Other studies also report proportional flow is a strong predictor of route selection (Kemp et al. 2005; Cavallo et al. 2015; Romine et al. 2021). Additionally, variables like DCC gate status (open / closed) will change routing and survival probabilities for fish traveling along the mainstem Sacramento River when they get to both Georgiana Slough and the DCC junctions. Newman and Brandes (2010) reported that exports affect routing of fish released in Georgiana Slough more than fish released at Ryde (upstream of Georgiana Slough on the Sacramento River) and the fraction of fish released in Georgiana Slough recovered at the fish collection facilities increased with increased exports.

Differences in monthly flows on the Sacramento River under Alternative 1 compared with the No Action Alternative may have impacts on juvenile Chinook salmon's routing and survival probabilities in the Sacramento River. These possible differences were evaluated using two quantitative models: STARS and ECO-PTM.

STARS

Average Sacramento River flows at Freeport December May are slightly greater under Alternative 1 compared with the No Action Alternative. The STARS model is responsive to modeled Freeport flows and daily operations of the DCC gates, both obtained from CalSim 3.

The STARS model provides predictions of routing and survival probabilities, in this section routing results are discussed. In the "survival" section survival results are discussed. Mean proportion of particles routed to the Interior Delta, via either Georgiana Slough or the DCC), averaged across all water year types by month under Alternative 1 ranged from greater than the No Action Alternative in December and January (up to 13.6% greater in January) to less than the No Action Alternative February through April (up to 1.5% less in April) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). The range of differences among months could have an adverse effect on outmigrating juveniles, particularly in December and January, but generally differences in flows are similar between scenarios.

ECO-PTM

Particles in ECO-PTM are released at Freeport on the Sacramento River on the first of the month between the months of December and March, to provide routing and survival estimates. ECO-PTM relies on hydrological inputs generated by CalSim 3 combined with swimming behaviors associated with the neutrally buoyant particles in ECO-PTM include upstream or downstream movement, holding behaviors, and swimming velocity. In this section routing estimates to the Interior Delta through Georgiana Slough are discussed. In the "survival" section through-Delta survival results are discussed. To represent a range of possible conditions in the Delta, results are binned and presented using OMR groupings: < -5,500 cfs; -5,000 cfs; -3,500 cfs; and -2,000 cfs.

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under Alternative 1 ranged from less than the No Action Alternative (up to 34% less under <-5,500 cfs) to equal to the No Action Alternative (under -5,000 cfs) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in the attachment. The decrease in routing to the Interior Delta could have a beneficial effect on outmigrating juveniles.

Summary

Two flow-based quantitative models suggest depending on considered variables, flows under Alternative 1 compared with the No Action Alternative may be adverse or beneficial for outmigrating juvenile Chinook salmon when results are binned by OMR grouping. Alternative 1 relative to the No Action Alternative using STARS suggests adverse impact on routing into the Interior Delta, particularly in December and January due to differences in flow. Alternative 1 relative to the No Action Alternative using ECO-PTM suggests a beneficial impact due to differences in flow with a smaller proportion routed to Interior Delta between December and March, particularly in OMR bins more negative than -5,500.

Potential changes to through Delta survival of winter-run Chinook salmon

Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. Juvenile Chinook salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010, 2018).

Differences in monthly flows on the Sacramento River under Alternative 1 compared with the No Action Alternative may have effects on juvenile Chinook salmon's routing and survival probabilities in the Sacramento River. These possible differences were evaluated using several quantitative models: STARS, ECO-PTM, the Delta Passage Model, IOS, and OBAN.

STARS

Average Sacramento River flows at Freeport December through May are slightly greater under Alternative 1 compared with the No Action Alternative. The STARS model is responsive to modeled Freeport flows and daily operations of the DCC gates, both obtained from CalSim 3.

The STARS model provides predictions of routing and survival probabilities, in this section survival results are discussed. In the "routing" section routing results are discussed. Mean predicted through-Delta survival of particles across all routes, averaged across all water year types by month under Alternative 1 ranged from less than the No Action Alternative in December and January (up to 7.6% less in December) to greater than the No Action Alternative February through April (up to 1% greater in April) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). The range of differences among months could have a minimal adverse effect on outmigrating juveniles, particularly in December and January, but generally differences in flows are similar between scenarios.

ECO-PTM

Particles in ECO-PTM are released at Freeport on the Sacramento River on the first of the month between the months of December and March, to provide routing and survival estimates. ECO-PTM relies on hydrological inputs generated by CalSim 3 combined with swimming behaviors associated with the neutrally buoyant particles in ECO-PTM include upstream or downstream movement, holding behaviors, and swimming velocity. In this section, through-Delta survival estimates are discussed. In the "routing" section routing estimates to the Interior Delta results are discussed. To represent possible conditions in the Delta, results are binned and presented using OMR groupings: < -5,500 cfs; -5,000 cfs; -3,500 cfs; and -2,000 cfs.

Mean through-Delta percent survival December through March under Alternative 1 ranged from less than the No Action Alternative (up to 22% less under -3,500 cfs) to greater than the No Action Alternative (up to 25% more under <-5,500 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in the attachment. The increase in survival under some OMR conditions could have a large beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have a large adverse effect on outmigrating juveniles.

Delta Passage Model (DPM)

The DPM simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River and estimates survival to Chipps Island. For this application, only survival of fish entering the Delta from the Sacramento River are evaluated. The DPM uses available time-series data and values taken from empirical studies or other sources to parameterize model relationships and inform uncertainty, thereby using the greatest amount of data available to dynamically simulate responses of smolt survival to changes in water management. (Attachment I.6, *Delta Passage Model*).

The major model functions in the DPM are as follows.

1. Delta Entry Timing, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon.
2. Fish Behavior at Junctions, which models fish movement as they approach river junctions.
3. Migration Speed, which models reach-specific smolt migration speed and travel time.
4. Route-Specific Survival, which models route-specific survival response to non-flow factors.
5. Flow-Dependent Survival, which models reach-specific survival response to flow.
6. Export-Dependent Survival, which models survival response to water export levels in the interior Delta reach.

Under Alternative 1, in all water year types, predicted mean survival of winter-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative. (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted survival to Chipps Island in all water year types are less than or equal to 0.01. There is not a substantial difference in predicted proportion of winter-run Chinook salmon surviving to Chipps Island between Alternative 1 and the No Action Alternative.

IOS: Through-Delta Survival

Under Alternative 1 in all water years, mean predicted through Delta survival of winter-run Chinook salmon juveniles is lower than when compared to the No Action Alternative (Attachment F.5, *Interactive Object-oriented Simulation Model*). However, the change in mean predicted river migration survival in all water year types are less than or equal to -0.013. There is not a substantial difference in predicted through Delta survival of winter-run Chinook salmon juveniles between Alternative 1 and the No Action Alternative.

OBAN: Delta Survival

Alternative 1 compared with the No Action Alternative may have an effect on juvenile winter-run Chinook salmon Delta survival due to differences in flow. These possible differences were evaluated using OBAN.

Delta survival under Alternative 1 was less than under the No Action Alternative (12.2% less, Table O-30). This decrease under Alternative 1 would have an adverse effect on outmigrating juvenile winter-run Chinook salmon.

Summary

Alternative 1 relative to the No Action Alternative is largely expected to have a potential adverse impact on survival of outmigrating juvenile winter-run Chinook salmon due to differences in flow.

O.4.9 Central Valley Spring-run Chinook Salmon ESU

O.4.9.1 Sacramento River

Spawning and Egg/Alevin Incubation

Spring-run Chinook salmon adults spawn from August through October (Williams 2006) with peak spawning in September (see Section O.1.3.2). Monitoring Spring-run Chinook salmon spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from fall-run Chinook salmon. Most spring-run Chinook salmon spawning occurs between the Keswick Dam and Ball Ferry Bridge (National Marine Fisheries Service 2017c). Fry emergence occurs up to three months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating spring-run Chinook salmon eggs and alevins potentially occur from August through January, peaking in December.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 1, mean spawning WUA is modestly higher in wet and above normal water year types and lower in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 1 and the No Action Alternative is a 15.5% increase in above normal water years. The largest reduction in estimated spawning habitat is a -2.7% decrease in critically dry water year types (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The monthly median value of spawning WUA under Alternative 1 is similar to the No Action Alternative in September and October, and higher in August (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA for all the modeled alternatives are substantially lower in August than in September or October. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in August than in the other two months (Table O-14). This results in lower spawning WUA results because the fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), which were used to estimate spring-run Chinook salmon spawning WUA, peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of suitable habitat availability analysis using the SIT LCM habitat models indicate that spawning habitat for spring-run in the upper Sacramento River may not a limiting factor under both the No Action Alternative and Alternative 1 (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The results of the two spawning habitat analyses based on CalSim3 simulated flows suggest that Alternative 1 may have a moderate (15.5%) increase in estimated spawning habitat during above normal water year types when compared to the No Action Alternative, but that spawning habitat may not be a limiting factor for spring-run Chinook salmon in the mainstem upper Sacramento River.

SIT Spring-run Lifecycle Model: Spawner Abundance

In the CVPIA spring-run Chinook salmon SIT life cycle model, mean spring-run Chinook salmon spawner abundance in the Central Valley under Alternative 1 is similar to the No Action Alternative, with up to 0.4% increase in above normal water year types and 0.09% decrease in dry water year types (Attachment F.3, *CVPIA SIT Spring-run LCM*). Under Alternative 1 and the No Action Alternative there is a year-to-year abundance decrease in dry years and an increase in all other water year types. Over the full model run period (1980–1999), abundance under Alternative 1 was equal to abundance under the No Action Alternative. Overall, the spawner abundance predicted by the CVPIA Spring-run life cycle model is expected to be similar under Alternative 1 and the No Action Alternative.

Redd Dewatering Analysis

Under Alternative 1, the spring-run Chinook salmon redd dewatering results show a consistent reduction in redd dewatering potential from wetter to drier water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation is expected for spring-

run Chinook salmon because their spawning occurs in the fall, with incubation extending into early winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater estimates of redd dewatering potential. In drier winters, flow fluctuations are reduced and fewer redds are potentially dewatered. Reductions in the estimates of redd dewatering potential from the No Action Alternative are larger than increases, with a maximum reduction of 39.2% in above normal years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The largest increase is 11.3% in dry water years. For individual months, redd dewatering under Alternative 1 is moderately lower for September spawning than the No Action Alternative and is about the same for October spawning (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that redd dewatering potential under Alternative 1 would be substantially lower than redd dewatering under the No Action Alternative during above normal and wet water year types and would be moderately higher in below normal and dry water years.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 48 for Keswick Dam and Table 50 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 54 for Keswick Dam and Table 56 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during September through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 60 for Keswick Dam and Table 62 for Red Bluff Diversion Dam.

Results for the three analyses are summarized in Table O-39. Table O-39, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 42.1°F to 55°F spawning initiation range analysis, there were eight (22.9% of total combinations during the period) and zero (0%) month-water year type combinations with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively (Table O-39). In addition, there were zero (0%) and two (5.7%) combinations with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. For the 59.9°F pathogen virulence threshold, there were zero combinations (0%) with favorable or unfavorable results below Keswick Dam, and 13 and 0 (37.1% and 0%) combinations with favorable and unfavorable results, respectively, at Red Bluff Diversion Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were 0 (0%) combinations with favorable and unfavorable results below Keswick Dam, and one (2.9%) favorable and four (11.4%) unfavorable results at Red Bluff Diversion Dam. These results suggest that there would be both positive and negative water temperature-related effects of Alternative 1 on spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

Table O-39. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Spawning and Egg/Alevin Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Below Keswick Dam							
Favorable	8 (22.9%)	5 (14.3%)	6 (17.1%)	5 (14.3%)	5 (14.3%)	9 (25.7%)	6 (17.1%)
Unfavorable	0 (0.0%)	2 (5.7%)	2 (5.7%)	3 (8.6%)	2 (5.7%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	1 (2.9%)	1 (2.9%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (5.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.9%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	3 (8.6%)	0 (0.0%)	0 (0.0%)	3 (8.6%)	3 (8.6%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	13 (37.1%)	14 (40.0%)	13 (37.1%)	11 (31.4%)	11 (31.4%)	11 (31.4%)	7 (20.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.7%)	3 (8.6%)
42.8°F–56°F RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	2 (5.7%)
Unfavorable	0 (0.0%)	2 (5.7%)	1 (2.9%)	3 (8.6%)	2 (5.7%)	1 (2.9%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	1 (2.9%)	1 (2.9%)	1 (2.9%)	4 (11.4%)	2 (5.7%)	1 (2.9%)	0 (0.0%)
Unfavorable	4 (11.4%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have adverse and beneficial impacts on spring-run Chinook salmon spawning and egg/alevin incubation due to differences in flow. Spawning habitat is not expected to be a limiting factor for spring-run Chinook salmon and is expected to moderately increase in above normal water year types under Alternative 1 compared to the No Action Alternative. There is a higher potential for redd dewatering during wet and above normal years. Water temperatures for spawning initiation below Keswick Dam are more favorable under Alternative 1 compared to the No Action Alternative and is the same for adult pathogen virulence at Red Bluff Diversion Dam. Egg incubation and fry emergence is comparable to the No Action Alternative at Keswick Dam and Red Bluff Diversion Dam. Alternative 1 relative to the No Action Alternative is expected to have a negligible impact on spring-run Chinook salmon spawning and egg/alevin incubation or the frequency of virulence due to water temperature below Keswick Dam.

Juvenile–Yearling Rearing and Emigration

Spring-run Chinook salmon juveniles rear in the Sacramento River primarily from November through June and most emigrate to the Delta during December and again in March and April (Roberts 2007) (see Section O.1.3.2, *Spring-run Chinook Salmon*). Migratory cues, such as increased flow and/or turbidity from runoff, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (National Marine Fisheries Service 2009a). Inundated floodplain habitats have been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001a, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 1, mean fry rearing WUA increases in wet water year types and decreases in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). No WUA curves were developed for spring-run Chinook salmon, so the fall-run curves were used to quantify spring-run Chinook salmon habitat. The largest increase in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 0.8% increase in wet water year types. The largest reduction in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 2.1 % decrease in critically dry water year types.

The monthly median value of fry rearing WUA under Alternative 1 has a 12% reduction in February and a 6% reduction in April below the No Action Alternative but is similar throughout the other fry rearing months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Fry rearing WUA median values for all the modeled alternatives are similar across December, January, and March, which are important months for rearing. The results during these three months show little variation in the third quartile of the WUA distributions. This limited variation occurs because the fry rearing WUA curves peak at the lowest flows encountered in the river and Keswick Dam flow releases are frequently low during these months in critically dry years when Shasta Reservoir is operated to rebuild storage volume (Table O-14). The first

quartile is much wider because a greater range of flows affect the fry rearing WUA values below the median. November and April have the lowest median WUA values across all alternatives. The occurrence of some higher rearing WUA values for April results from the installation of the ACID dam for that month, which results in higher WUA values in Segment 6 of the river.

The results of the spring-run Chinook salmon fry rearing habitat analysis suggest that Alternative 1 may have a minor (less than 2.5%) increase and/or decrease in estimated spring-run Chinook salmon fry rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in February (12%) in comparison to the No Action Alternative.

Juvenile rearing habitat analyses

Under Alternative 1, mean juvenile rearing WUA increases in wet and above normal water year types and decreases in below normal, dry, and critically dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 1.0% increase in above normal water years. The largest reduction in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 0.5% decrease in critically dry water year types.

The monthly median value of juvenile rearing WUA under Alternative 1 is similar to the No Action Alternative January through May (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under all of the modeled alternatives are similar for January through March, but they are generally lower for April and May. For the January through March period, as described above for spring-run Chinook salmon fry rearing WUA, the third quartiles of the WUA distributions have high values and reduced variation. This occurs because, as described for the fry rearing WUA curves, the juvenile rearing WUA curves peak at the lowest flows encountered in the river (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and low flows are frequent during January through March in dry and critically dry years when Shasta Reservoir is operated to rebuild storage (Table O-14).

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for spring-run Chinook salmon in the upper Sacramento River have a 0.4% to -1.5% difference between the months of January and May (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in March and the greatest reduction in estimated habitat may occur in May under Alternative 1 in comparison to the No Action Alternative.

The results of the two spring-run Chinook salmon juvenile rearing habitat analyses suggest that Alternative 1 may have a minor (less than 1.5%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Alternative 1 shows a substantial increase in stranding of spring-run Chinook salmon juveniles from critically dry to wet water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The

higher mean stranding levels for spring-run Chinook salmon fry during wetter water year types likely results because of periodic storms and high runoff that produce increased variability of flow. Spring-run Chinook salmon fry rearing occurs primarily during late fall and winter. Alternative 1 shows the highest stranding in February and similar stranding levels in November, December, and January (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Alternative 1 has higher juvenile stranding of spring-run Chinook salmon fry than the No Action Alternative in all water year types except critically dry water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The largest difference is a 12.8% reduction for critically dry years. The largest increases are 9.3% and 7.7% in wet years and below normal water years, respectively.

Overall, spring-run Chinook salmon juvenile stranding for fry is higher under Alternative 1 in comparison to the No Action Alternative, except for substantially lower stranding in critically dry water years.

Survival and Travel Time: XT and Flow Survival Threshold Models

Differences in daily flows (Upper Sacramento River Daily Operations Model, USRDOM) under Alternative 1 compared with the No Action Alternative may have effects on juvenile Chinook salmon's travel time and survival probabilities in the Upper Sacramento River. These possible differences were evaluated using several quantitative models. For a detailed description of how flows under Alternative 1 may impact juveniles and yearlings' travel time and survival probabilities in the Upper Sacramento River, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.1, *Survival and Travel Time: XT and Flow Survival Threshold Models*).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for juvenile growth, smoltification, and predation vulnerability during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 66 for Keswick Dam, Table 68 for RBDD, and Table 70 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating juveniles during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 74 for Keswick Dam, Table 76 for RBDD, and Table 78 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for yearling growth, smoltification, and predation vulnerability are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 82 for Keswick Dam during April through December, Table 84 for RBDD during April through December, and Table 98 for Hamilton City during October through December (migration only). Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating yearlings are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 88 for Keswick Dam during April through December, Table 90 for RBDD during April through December, and Table 106 for Hamilton City during October through December (migration only).

Results for the four analyses are summarized in Table O-40. Table O-40, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F juvenile optimum water temperature range under Alternative 1, there were one to three month-water year type combinations (2.5% to 7.5% of total combinations during the period) with favorable results depending on location (Table O-40). There were zero to six combinations (0% to 15.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 1, there would be no combinations with either favorable or unfavorable results at any location. For the 55.4°F to 68°F yearling optimum water temperature range under Alternative 1, there would be two to five combinations with favorable results (4.4% to 11.1%) with favorable results depending on location. There would be zero to six combinations (0% to 13.3%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating yearlings under Alternative 1, there would be no combinations with either favorable or unfavorable results at any location. These results indicate that there would be a mix of positive and negative water temperature-related conditions under Alternative 1 related to optimum water temperatures on juveniles and yearlings but negligible effects of Alternative 1 on lethal water temperatures.

Table O-40. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Juvenile to Yearling Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Below Keswick Dam							
Favorable	2 (5.0%)	1 (2.5%)	1 (2.5%)	2 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	6 (15.0%)	3 (7.5%)	3 (7.5%)	3 (7.5%)	3 (7.5%)	6 (15.0%)	2 (5.0%)
Red Bluff Diversion Dam							
Favorable	1 (2.5%)	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	0 (0.0%)
Unfavorable	1 (2.5%)	0 (0.0%)	0 (0.0%)	1 (2.5%)	2 (5.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	3 (7.5%)	1 (3.3%)	2 (6.7%)	1 (3.3%)	1 (3.3%)	1 (2.5%)	2 (6.7%)
Unfavorable	0 (0.0%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (2.5%)	1 (3.3%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR YEARLING GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Below Keswick Dam							
Favorable	2 (4.4%)	2 (4.4%)	2 (4.4%)	4 (8.9%)	2 (4.4%)	0 (0.0%)	0 (0.0%)
Unfavorable	6 (13.3%)	3 (6.7%)	5 (11.1%)	3 (6.7%)	3 (6.7%)	8 (17.8%)	5 (11.1%)
Red Bluff Diversion Dam							
Favorable	5 (11.1%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (4.4%)	2 (4.4%)	1 (2.2%)	1 (2.2%)	3 (6.7%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	4 (26.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR YEARLINGS							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 and the No Action Alternative is expected to have minor adverse and minor beneficial impacts on spring-run Chinook salmon fry and juvenile rearing habitat due to differences in flow. Alternative 1 relative to the No Action Alternative could have an adverse impact, depending on water year type, on stranding except in critically dry water years, when there would be a substantial beneficial impact on stranding due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have adverse and beneficial impacts on growth, smoltification, and predation vulnerability, depending on life stage and location due to differences in water temperature. Water temperatures above the incipient lethal limit are not expected to change in frequency under Alternative 1 and the No Action Alternative.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon enter the San Francisco Estuary from the Pacific Ocean to begin their upstream spawning migration in late January and early February (California Department of Fish and Wildlife 1998). Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). While maturing, adults hold in deep pools with cold water. Documentation of holding locations in the Sacramento River were not identified.

Spring-run Chinook salmon adults enter the Sacramento River from March to September, primarily in May and June (Moyle 2002; Yoshiyama et al. 1998). In the upper Sacramento River, migration extends from mid-March through July with peak migration in late May and early June (California Department of Fish and Wildlife 1998).

Potential changes to spring-run Chinook salmon from seasonal operations

CalSim 3 Flows

During the January through June/July period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 1 at Sacramento River below Keswick Dam, below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough would generally be similar to or greater than flows under the No Action Alternative, except during February of a critically dry water year type below Keswick Dam when flows would be as much as 6% less. Flows under Alternative 1 in April of a critically dry water year type would be more than 5% greater than flows under the No Action Alternative at all four locations and up to 22% greater at Red Bluff Diversion Dam. Flows at Hamilton City under Alternative 1 would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 1 between January and June/July would be greater than 5,500 cfs at Wilkins Slough and greater than 7,500 cfs at Hamilton City (Table O-14 through Table O-17).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during March through September are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 40 for Keswick Dam, Table 42 for RBDD, and Table 44 for Hamilton City.

Results for the analysis are summarized in Table O-41. Table O-41, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1, there were no month-water year type combinations (0% of total combinations during the period) with favorable results (Table O-41). There were zero and two combinations (0% and 5.7%) with unfavorable results, depending on location. These results suggest that there would be mostly negligible water temperature-related effects of Alternative 1 on spring-run Chinook salmon migration and holding in the Sacramento River.

Table O-41. Summary of Results for Water Temperature Analyses for spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL ADULT MIGRATION RANGE							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (5.7%)	1 (2.9%)	0 (0.0%)	1 (2.9%)	1 (2.9%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	0 (0.0%)	2 (5.7%)	2 (5.7%)
Unfavorable	0 (0.0%)	1 (2.9%)	1 (2.9%)	1 (2.9%)	2 (5.7%)	1 (2.9%)	2 (5.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have no impact to a beneficial impact, depending on location and month, on upstream migrating and holding adult spring-run Chinook salmon due to differences in flow, and average monthly flows at Hamilton City and Wilkins Slough are high enough to allow upstream passage. Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on upstream migration and holding adult spring-run Chinook salmon due to differences in water temperature.

O.4.9.2 Clear Creek

Spawning and Egg Incubation

Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities to promote higher oxygen levels. Spawning in Clear Creek normally occurs between mid-August and early October, peaking in September (Moyle 2002).

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 1, mean spawning WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean spawning WUA under Alternative 1 in comparison to the No Action Alternative. The largest reduction in estimated spawning habitat is a 79.9% decrease in critically dry water year types. On average across all water year types, there is a 79.2% reduction in estimated spawning habitat under Alternative 1.

The mean values of spawning WUA by month are much lower under Alternative 1 compared to the other alternatives and the No Action Alternative (Attachment O.1, Clear Creek Weighted Usable Area Analysis). September and October are expected to have similar values under Alternative 1.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for spring-run in Clear Creek may be a limiting factor under all of the modeled alternatives and that spawning habitat may decrease 72-76.3% in September and October for Alternative 1 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The results of the two spawning habitat analyses suggest that Alternative 1 may have a substantial adverse effect, as spring-run Chinook salmon spawning habitat may decrease on average by 79.2% across all water year types in Clear Creek when compared to the No Action Alternative, and that spawning habitat may be a limiting factor for spring-run Chinook salmon in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 52 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 58 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during September through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 6 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-42. Table O-42, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0% of total combinations during the period) with favorable results and two combinations (5.7%) with unfavorable results below Whiskeytown Dam (Table O-42). For the 59.9°F pathogen virulence threshold, there were zero combinations (0%) with favorable results and one combination (2.9%) with unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero (0%) combinations with favorable results and two combinations (5.7%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on spring-run Chinook salmon spawning in Clear Creek.

Table O-42. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Spawning and Egg/Alevin Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (5.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
42.8°F–56°F RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (5.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have a substantial adverse impact on spawning habitat area due to a decrease in flows and minor negative water temperature-related effects spawning and egg incubation.

Juvenile–Yearling Rearing and Emigration

While the majority of juvenile spring-run Chinook salmon outmigrate as fry, a proportion rears in Clear Creek through the spring and summer and emigrates as subyearlings with the first rainstorms in the fall or winter following their birth (National Marine Fisheries Service 2014a). Spring-run Chinook salmon outmigration from Clear Creek occurs during late October through late April with peak emigration of juveniles occurring in November, and few fish exiting through the end of May.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 1, mean fry rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean fry rearing WUA under Alternative 1 in comparison to the No Action Alternative. The largest reduction in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is an 8.0% decrease in above normal water year types.

The mean values of fry rearing WUA by month are lower under Alternative 1 compared to the other alternatives and the No Action Alternative, from November through March (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). All five months have similar expected fry rearing WUA values.

The results of the spring-run fry rearing habitat analysis suggest that Alternative 1 may have a minor (less than 8%) decrease in estimated spring-run Chinook salmon fry rearing habitat across all water year types in Clear Creek.

Juvenile Rearing Habitat Analyses

Under Alternative 1, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 1 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 56.5% decrease in wetter water year types. On average across all water year types, there is a 55.7% reduction in estimated juvenile rearing habitat under Alternative 1.

The mean values of juvenile rearing WUA by month are much lower under Alternative 1 compared to the other alternatives and the No Action Alternative, from April through August (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). All five months have similar expected juvenile rearing WUA values.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for spring-run Chinook salmon in Clear Creek may decrease 31.3-56.4% April through August under Alternative 1 compared to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest decrease in estimated habitat may occur in June under Alternative 1 in comparison to the No Action Alternative.

The results of the two spring-run Chinook salmon juvenile rearing habitat analyses suggest that Alternative 1 may have a substantial adverse effect, as rearing habitat may decrease on average 55.7% across all water year types in comparison to the No Action Alternative. The largest decreases are expected in June during the juvenile rearing period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for juvenile growth, smoltification, and predation vulnerability during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 72 below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating juveniles during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 80 below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for yearling growth, smoltification, and predation vulnerability are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 86 below Whiskeytown Dam April through December. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating yearlings are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 92 below Whiskeytown Dam for April through December.

Results for the four analyses are summarized in Table O-43. Table O-43, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F juvenile optimum temperature range under Alternative 1, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-43). For the 75.2°F UILT for rearing and migrating juveniles, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam. For the 55.4°F to 68°F yearling optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown. Dam For the 75.2°F UILT for rearing and migrating yearlings, there were no combinations (0%) with favorable results and one combination (2.2%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on spring-run Chinook salmon juvenile and yearling rearing and emigration in Clear Creek.

Table O-43. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Juvenile and Yearling Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR YEARLING GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR YEARLINGS							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.2%)	2 (4.4%)	1 (2.2%)	2 (4.4%)	2 (4.4%)	0 (0.0%)	2 (4.4%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative show a decrease in spring-run Chinook salmon fry rearing habitat and juvenile rearing habitat due to differences in flow. Fry rearing habitat would have a minor decrease during all water years, but juvenile rearing habitat would be substantially adversely impacted due to the average decrease of 56% over all water year types. Differences in water temperature between Alternative 1 and the No Action Alternative are negligible so are not expected to impact juvenile and yearling rearing and emigration.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon migrate into Clear Creek from April to August, and peak passage occurs in May and June (Clear Creek Technical Team 2018; Giovannetti et al 2013). Adults distribute throughout Clear Creek and hold in deep pools throughout the summer from Whiskeytown Dam (river mile 18.3) as far downstream as river mile 4.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

CalSim 3 Flows

During the April through August period of adult spring-run Chinook salmon immigration and holding in Clear Creek, the mean monthly flows under Alternative 1 will be reduced from April to August which range from 66% in July in critically dry water years, up to 84% in August during most water years. Flows will be 50 cfs during all of the months, except in August of a critically dry year, which would be 45 cfs (Table O-23).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during March through September are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 46 below Whiskeytown Dam.

Results for the analysis are summarized in Table O-44. Table O-44, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 37.9°F to 68°F successful adult migration range, there were zero month-water year type combinations (0% of total combinations during the period) with favorable results and one combination (2.9%) with unfavorable results below Whiskeytown Dam (Table O-44). These results suggest that there would be negligible water temperature-related effects of Alternative 1 on spring-run Chinook salmon adult upstream migration and holding in Clear Creek.

Table O-44. Summary of Results for Water Temperature Analyses for Spring-run Chinook Salmon Upstream Migration and Holding in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL ADULT MIGRATION RANGE							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have a substantial adverse impact on upstream migrating and holding adult spring-run Chinook salmon, since flows will be substantially reduced. Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on upstream migrating and holding adult spring-run Chinook salmon due to differences in water temperature.

O.4.9.3 Bay-Delta

Juvenile–Yearling Rearing and Emigration

Juvenile spring-run Chinook salmon show two distinct out-migration patterns in the Central Valley: out-migrating to the Delta and ocean during their first year of life as YOY or holding over in their natal streams and out-migrating the following fall/winter as yearlings. YOY spring-run Chinook salmon presence in the Delta peaks during April and May, as suggested by the recoveries of Chinook salmon in the CVP and SWP salvage operations and the Chipps Island trawls of a size consistent with the predicted size of spring-run fish at that time of year.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Differences in hydrology in the Delta under Alternative 1 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using several quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions.

Zone of Influence

Differences in hydrology under Alternative 1 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. These possible differences were evaluated using DSM2-HYDRO outputs. For a detailed description of how flows under Alternative 1 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2, *Zone of Influence*).

Flow into Junctions

Alternative 1 compared with the No Action Alternative may have effects on the flow into the Head of Old River and CVP junctions due to differences in flow routing. These possible differences were evaluated using DSM2-HYDRO outputs. For a detailed description of how flows under Alternative 1 may impact the flow at Head of Old River and CVP, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2, *Flow into Junctions*).

Summary

Alternative 1 relative to the No Action Alternative is expected to influence flow into the Head of Old River and CVP junctions. Under Alternative 1, there is expected to be possibly less flow into CVP under OMR -2,000 and -5,000 and possibly less flow into HOR under all OMR groups. Impacts of pumping under both Alternative 1 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus is more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Spring-run Chinook Salmon

Differences in exports and flows under Alternative 1 compared with the No Action Alternative may have effects on juvenile spring-run Chinook salmon entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the quantitative models, Salvage Density and Negative Binomial.

Salvage Density and Negative Binomial

Predictions from the salvage density model for genetic and LAD spring-run Chinook salmon include mean monthly total exports. Predictions from the negative binomial loss model for LAD spring-run Chinook salmon include mean monthly total exports and mean monthly San Joaquin River flows at Vernalis. Table O-19 shows modeled mean monthly total exports at SWP and CVP and table O-29 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of LAD spring-run Chinook salmon at SWP Banks Pumping Plant for all the months January through June, of all water year types Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 150% greater in a above normal water year type (Table O-45). Predicted average monthly loss of LAD spring-run Chinook salmon at CVP Jones Pumping Plant for all the months December through June of all water year types Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 12% greater, in below normal water year types (Table O-46). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Table O-45. Predicted Average Monthly Loss of LAD SR at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	6,425	9463 (47%)	9347 (45%)	9334 (45%)	9110 (42%)	9125 (42%)	2308 (-64%)	9181 (43%)	6: Jan–June
Above Normal	2273	5677 (150%)	4920 (116%)	4914 (116%)	3842 (69%)	3801 (67%)	1995 (-12%)	4929 (117%)	6: Jan–June
Below Normal	1196	2403 (101%)	2015 (68%)	2043 (71%)	1579 (32%)	1616 (35%)	1205 (1%)	2010 (68%)	4: Mar–June
Dry	900	1675 (86%)	1433 (59%)	1434 (59%)	1043 (16%)	1037 (15%)	922 (2%)	1442 (60%)	3: Mar–May
Critically Dry	84	105 (24%)	95 (13%)	86 (2%)	86 (2%)	90 (6%)	91 (8%)	102 (21%)	4: Feb–May

Table O-46. Predicted Average Monthly Loss of LAD SR at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	1,220	1228 (1%)	1259 (3%)	1260 (3%)	1205 (-1%)	1202 (-2%)	227 (-81%)	1269 (4%)	7: Dec–June
Above Normal	1042	1111 (7%)	1062 (2%)	1061 (2%)	946 (-9%)	942 (-10%)	188 (-82%)	1067 (2%)	7: Dec–June
Below Normal	674	757 (12%)	700 (4%)	689 (2%)	606 (-10%)	603 (-11%)	234 (-65%)	707 (5%)	6: Jan–June
Dry	472	516 (9%)	468 (-1%)	467 (-1%)	410 (-13%)	408 (-13%)	109 (-77%)	469 (-1%)	5: Dec, March–June
Critically Dry	60	63 (5%)	60 (0%)	64 (5%)	62 (3%)	62 (2%)	17 (-72%)	61 (1%)	5: Jan–May

Predicted average monthly salvage of LAD spring-run Chinook salmon at the Delta fish collection facilities for the months of March through June under Alternative 1 was greater than predicted loss under the No Action Alternative, up to 154% greater for the above normal water year type. (Table O-47). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

Table O-47. Predicted Average Monthly Salvage of Juvenile Spring-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type, March–June

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	1615	1906 (18%)	2183 (35%)	2188 (35%)	1959 (21%)	1940 (20%)	209 (-87%)	2212 (37%)
Above Normal	115	292 (154%)	224 (95%)	223 (94%)	121 (5%)	120 (4%)	55 (-52%)	226 (97%)
Below Normal	134	278 (108%)	207 (55%)	205 (53%)	167 (25%)	168 (26%)	65 (-51%)	201 (50%)
Dry	48	88 (83%)	63 (30%)	63 (29%)	50 (3%)	50 (3%)	23 (-52%)	63 (31%)
Critically Dry	30	41 (34%)	36 (18%)	35 (17%)	35 (16%)	36 (17%)	18 (-42%)	36 (20%)

Summary

Alternative 1 relative to the No Action Alternative is expected to have a potential adverse impact on the entrainment of the genetic and LAD identified juvenile spring-run Chinook salmon in the Delta at both fish facilities due to differences in flow, supported by results from two quantitative models.

Potential Changes to Routing of Spring-run Chinook Salmon

ECO-PTM

Alternative 1 compared with the No Action Alternative may have effects on juvenile Chinook salmon's routing to Interior Delta via Georgiana Slough in the Delta due to differences in flows. This possible difference was evaluated using ECO-PTM. For a detailed description of how flows under Alternative 1 may impact spring-run Chinook salmon routing, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2).

Summary

Alternative 1 relative to the No Action Alternative using ECO-PTM suggests a beneficial impact due to differences in flow with a smaller proportion routed to Interior Delta between December and March, particularly in OMR bins more negative than -5,500.

Potential changes to through Delta survival of spring-run Chinook salmon

ECO-PTM

For a detailed description of how flows under Alternative 1 may impact spring-run Chinook salmon through-Delta survival, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2).

Delta Passage Model

Under Alternative 1, in all water year types except critically dry water years, predicted mean survival of spring-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted survival to Chipps Island in all water year types is less than ± 0.01. There is not a substantial difference in predicted proportion of spring-run Chinook salmon surviving to Chipps Island between Alternative 1 and the No Action Alternative.

Summary

Alternative 1 relative to the No Action Alternative using the ECO-PTM suggests a beneficial impact with a smaller proportion of spring-run Chinook salmon routed to Interior Delta between December and March due to differences in flow, particularly in OMR bins more negative than -5,500. For the DPM, there is not a meaningful difference of survival for spring-run Chinook salmon between Alternative 1 and the No Action Alternative.

O.4.10 California Central Valley Steelhead DPS

O.4.10.1 Sacramento River

Spawning and Egg Incubation

Steelhead mostly use the Sacramento River as a migratory corridor for reaching other tributaries to spawn. Data on steelhead spawning in the mainstem Sacramento River is limited and likely restricted to the area upstream of Red Bluff (National Marine Fisheries Service 2009a). No steelhead specific spawner surveys occur in the upper Sacramento River. Data from recent surveys for the four runs of Chinook salmon have found carcasses of *O. mykiss* but the majority are thought to be resident trout adults (Killam 2022). Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In the Sacramento River, estimated incubation timing based on spawning is December through June.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 1, differences in mean spawning WUA are higher in dry and critically dry water year types, and lower in wet, above normal, and below normal water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 1 and the No Action Alternative is a 1.0% increase in critically dry water years. The largest reduction in estimated spawning habitat is a -2.0% decrease in above normal water year types.

The monthly median value of spawning WUA under Alternative 1 is similar to the No Action Alternative January through April (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are relatively similar in January through March. In April, the median values of spawning WUA are higher across all alternatives when compared to the other spawning months. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently lowest in April when compared to other spawning months (Table O-14). This results in lower spawning WUA results because the steelhead spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 4,000 to 7,000 cfs).

The results of the suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for steelhead in the upper Sacramento River may increase in April under all alternatives compared to the other spawning months (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). Lack of consistent spawner estimates for steelhead prevented Reclamation staff from calculating spawner limitation ratios for this species.

The results of the two spawning habitat analyses based on CalSim3 simulated flows suggest that Alternative 1 may have a minor (less than 2.1%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. Out of the four months of steelhead spawning, April has the highest estimated spawning WUA across all alternatives.

Redd Dewatering Analysis

The results for both the No Action Alternative and Alternative 1 show large and consistent variations in percentage of steelhead redds dewatered with water year type, varying from high redd dewatering in wet water years to low redd dewatering in critically dry water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation reflects flow conditions for the winter and early spring months, when steelhead spawning and incubation occurs. During wet winters and springs, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. Differences in mean redd dewatering potential between Alternative 1 and the No Action Alternative are generally small, except in critically dry water years, for which mean redd dewatering is 22.6% lower under Alternative 1 than under the No Action Alternative (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The apparent magnitude of this relative difference is misleading because the absolute difference is only 1.1%. The largest increase in mean redd dewatering potential is 5.5% in below normal water year types.

Overall, the results indicate that redd dewatering potential under Alternative 1 would be largely similar to results under the No Action Alternative, except in critically dry water years when redd dewatering would be substantially lower under Alternative 1. However, in terms of absolute change all the differences are modest.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis* Table 134 for Keswick Dam and Table 136 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 140 for Keswick Dam and Table 142 for RBDD. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 170 for Keswick Dam and Table 172 for RBDD.

Results for the three analyses are summarized in Table O-48. Table O-48, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 45.5°F to 55°F successful spawning range analysis, there were eight and one month-water year type combinations (26.7% and 3.3% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-48). There were zero and one combinations (0% and 3.3%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were zero and eight combinations (0% and 26.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. For the 45°F to 52°F range for optimal egg incubation, there were 12 and zero combinations (34.3% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were four and two combinations (11.4% and 5.7%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be frequent positive water temperature-related effects and some negative effects of Alternative 1 on steelhead spawning and egg incubation in the Sacramento River.

Table O-48. Summary of Results for Water Temperature Analyses for Steelhead Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
45°F–55°F RANGE FOR SUCCESSFUL SPAWNING							
Below Keswick Dam							
Favorable	8 (26.7%)	5 (16.7%)	6 (20.0%)	5 (16.7%)	5 (16.7%)	9 (30.0%)	3 (10.0%)
Unfavorable	0 (0.0%)	1 (3.3%)	1 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	1 (3.3%)	1 (3.3%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	8 (26.7%)	5 (16.7%)	5 (16.7%)	5 (16.7%)	5 (16.7%)	4 (13.3%)	2 (6.7%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)
45°F–52°F RANGE FOR OPTIMAL EGG INCUBATION							
Below Keswick Dam							
Favorable	12 (34.3%)	8 (22.9%)	8 (22.9%)	7 (20.0%)	7 (20.0%)	8 (22.9%)	1 (2.9%)
Unfavorable	4 (11.4%)	4 (11.4%)	5 (14.3%)	3 (8.6%)	3 (8.6%)	5 (14.3%)	6 (17.1%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (5.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	2 (5.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Removal of Sacramento River Pulse Flows

The removal of the spring pulse flows component under Alternative 1 compared to the No Action Alternatives may impact steelhead spawning behavior and redd dewatering. However, redd surveys occurred under the No Action Alternative during the pulse flow period and redd dewatering was not observed.

Summary

There are expected minor adverse and moderate beneficial impacts of seasonal operations on steelhead spawning and egg incubation based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows may increase and/or decrease on spawning habitat area and may decrease redd dewatering potential during critically dry water year types. There may be beneficial impacts to spawning behavior from removal of spring pulse flows. Water temperatures above the successful spawning and optimal egg incubation criteria may overall decrease in frequency below Keswick Dam. Water temperatures above the pathogen virulence threshold may also decrease in frequency at RBDD.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in the Sacramento River. The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station in lower Clear Creek indicates outmigration into the Sacramento River with median passage starting in November and ending in June, with peak passage between April and June (Schraml and Chamberlain 2019a, 2019b, 2020, 2021).

Potential Changes to Steelhead from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 1, mean fry rearing WUA increases in wet and above normal water year types and decreases in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). WUA curves were not developed for steelhead, so the late fall-run Chinook salmon curves were used to quantify steelhead habitat. The largest increase in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 1.9% increase in above normal water year types. The largest reduction in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 1.2% decrease in below normal water year types.

The monthly median value of fry rearing WUA under Alternative 1 has an 8% reduction in April and a 5% reduction in October below the No Action Alternative. The median values are similar throughout the other fry rearing months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The fry rearing WUA values under the modeled alternatives are highly variable across the months, April through October, but are generally highest in April and October (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). WUA values of the fry rearing WUA curve are lowest in the range of approximately 7,000 cfs to 13,000 cfs in Segment 5 (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and flows in this range are more frequent during May through August (Table O-14).

The results of the steelhead fry rearing habitat analysis based on CalSim3 simulated flows suggest that Alternative 1 in comparison to the No Action Alternative may have a minor (less than 2%) increase and/or decrease in estimated steelhead fry rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in April (8%).

Juvenile Rearing Habitat Analyses

Under Alternative 1, mean juvenile rearing WUA increases in wet and above normal water year types and decreases in below normal, dry, and critically dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The upper and lower limits of the range in WUA values are determined by the ranges of the juvenile rearing WUA curves for late fall-run Chinook salmon since there were no reliable WUA curves for steelhead. The analysis includes all months because steelhead juveniles may reside in freshwater for a year or more before emigrating to the ocean. The largest increase in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 0.9% increase in above normal water years. The largest reduction in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 0.4% decrease in critically dry water year types.

The monthly median value of juvenile rearing WUA under Alternative 1 is similar to the No Action Alternative most months of the year but constitutes a 7% reduction under Alternative 1 in June (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under the modeled alternatives are similar December through March, and gradually decrease until the lowest estimated values in July. As discussed previously for spring-run rearing WUA and steelhead spawning WUA, the high WUA values with low variability in the third quartile for December through March result from the peaking of the WUA curve at the lowest flows (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and frequent low Keswick Dam flow releases during these months to build Shasta Reservoir storage (Table O-14). The wide range of values in the first quartile of these months reflects the high frequency and variability of higher flows in these wet months. The low juvenile rearing WUA values June through August result from releases in the summer months above 10,000 cfs and estimated peak juvenile rearing at flows below 5,000 cfs.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that juvenile rearing instream habitat for steelhead in the upper Sacramento River have a 5.7% to -4.8% difference from January through December (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in August and the greatest reduction in estimated habitat may occur in June under Alternative 1 in comparison to the No Action Alternative.

The results of the two steelhead juvenile rearing habitat analyses suggest that Alternative 1 compared to the No Action Alternative may have a negligible (less than 1%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in June (4.8-7%) in the mainstem upper Sacramento River.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Mean stranding of

steelhead fry under Alternative 1 shows substantial variation with water year type, with wet years having the highest stranding and dry and critically dry years the lowest (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher mean stranding levels for steelhead fry during wetter water year types likely results because of periodic storms and high runoff that produce increased variability of flow. Steelhead fry rearing occurs primarily during late winter and spring. Alternative 1 shows the highest stranding in February, with the median level trending down over the next three months (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Differences in juvenile stranding of steelhead fry between Alternative 1 and the No Action Alternative are large, ranging from reductions of 12.6% and 10.6% for dry and critically dry water year types, respectively, to increases of 16.1% and 9.0% for above normal and wet water year types, respectively (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, differences between Alternative 1 and the No Action Alternative in steelhead juvenile stranding for fry vary depending on water year type, with wetter water year types showing increases in stranding and drier water years showing reductions.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperature range year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 182 for Keswick Dam and Table 184 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 188 for Keswick Dam, Table 190 for Red Bluff Diversion Dam, and Table 192 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 55°F upper limit of successful smoltification during January through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 196 for Keswick Dam, Table 198 for Red Bluff Diversion Dam, and Table 200 for Hamilton City.

Results for the three analyses are summarized in Table O-49. Table O-49, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F upper limit of optimum temperature range under Alternative 1, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-49). There were zero to one combination (0% to 1.7%) with unfavorable results depending on location. For the 59.9°F juvenile pathogen virulence threshold, there would be 0 to 13 combinations (0% to 21.7%) with favorable results depending on location. There were zero to five combinations (0% to 8.3%) with unfavorable results depending on location. For the 55°F upper limit of successful smoltification, there were one to eight combinations (4.0% to 32.0%) with favorable results depending on location. There were zero to one combination (0% to 4.0%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 1 on steelhead juvenile rearing and emigration.

Table O-49. Summary of Results for Water Temperature Analyses for Steelhead Juvenile Rearing and Emigration in the Sacramento River for each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66.2°F UPPER LIMIT OF OPTIMUM TEMPERATURE RANGE FOR JUVENILE STEELHEAD GROWTH, ASSUMING MAXIMUM RATION LEVELS							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	1 (1.7%)
Unfavorable	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)	0 (0.0%)
59.9°F JUVENILE PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	3 (5.0%)	0 (0.0%)	0 (0.0%)	3 (5.0%)	3 (5.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	13 (21.7%)	14 (23.3%)	13 (21.7%)	11 (18.3%)	11 (18.3%)	11 (18.3%)	7 (11.7%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (3.3%)	3 (5.0%)
Hamilton City							
Favorable	2 (3.3%)	1 (1.7%)	1 (1.7%)	0 (0.0%)	1 (1.7%)	1 (1.7%)	1 (1.7%)
Unfavorable	5 (8.3%)	1 (1.7%)	0 (0.0%)	1 (1.7%)	1 (1.7%)	3 (5.0%)	0 (0.0%)
55°F UPPER LIMIT OF SUCCESSFUL SMOLTIFICATION							
Below Keswick Dam							
Favorable	8 (32.0%)	5 (20.0%)	5 (20.0%)	5 (20.0%)	5 (20.0%)	8 (32.0%)	3 (12.0%)
Unfavorable	0 (0.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	1 (4.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Hamilton City							
Favorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Removal of Sacramento River Pulse Flows

There may be adverse and beneficial impacts due to the removal of the spring pulse flows component under Alternative 1 compared with the No Action Alternative. The removal of the component may reduce fry stranding potential and predation from sudden drops in flow during a spring pulse event. There may be adverse impacts due to increased travel time for juvenile outmigration.

Summary

There are expected moderate adverse and moderate beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows may have a minor increase and/or decrease on fry and juvenile rearing habitat area. Changes in flows may increase fry stranding during wetter water year types and decrease fry stranding during drier water year types. Water temperatures above the smoltification criteria may decrease in frequency below Keswick Dam. Water temperatures above the pathogens and disease criteria may decrease in frequency at RBDD but may increase in frequency at Hamilton City under Alternative 1.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). Historical data at the Fremont Weir have shown that adult steelhead migrate upstream in the Sacramento River during most months of the year, beginning in July, peaking in September, and continuing through March (Hallock 1989; McEwan 2001; Hallock et al. 1957).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

A flow threshold of 3,250 cfs has been used to evaluate the potential for adverse effects on steelhead migrating and holding adults in the Sacramento River (Long-term Operations 2019 EIS). Flows in the Sacramento River rarely drop below this level, and adults have not been observed to experience passage delays, crowding, or other adverse effects at this flow. Therefore, it represents a reasonable threshold for evaluating the potential for adverse effects on migrating and holding adults.

During the steelhead adult upstream migration and holding period, approximately July through March, CalSim 3 modeling of Sacramento River mean monthly flows at Wilkins Slough are below the minimum flow in critically dry years September under the No Action Alternative and flows are expected to have a 6% reduction under Alternative 1 (Table O-16). Flows in the Sacramento River at Wilkins Slough range from about 2,846 cfs in October of critically dry water years to about 19,907 cfs in February of wet water years during the adult migration period (Table O-16). Flows in the Sacramento River at RBDD range from about 4,660 cfs in October of critically dry water years to about 37,076 cfs in January of wet water years during the adult migration period (Table O-15). Under Alternative 1, Reclamation will operate minimum instream flows at 2,300 cfs in March, July, and August, and 3,250 cfs from September through February but the schedule may change in critically dry water years (WRO Order 90-5). Since peak adult migration occurs around September, there may be negative effects to adult steelhead in September of critically dry years if flows are reduced at Wilkins Slough.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range for minimal migration impairment during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 110 for Keswick Dam, Table 112 for Red Bluff Diversion Dam, and Table 114 for Hamilton City. Results for the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 118 for Keswick Dam, Table 120 for Red Bluff Diversion Dam, and Table 122 for Hamilton City. Results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for adult migration and holding during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 126 at Keswick Dam, Table 128 for Red Bluff Diversion Dam, and Table 130 for Hamilton City.

Results for the three analyses are summarized in Table O-50. Table O-50 as described in Section O.4.8.1 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 41°F to 66.2°F range for minimal migration impairment, there were zero to one month-water year type combinations (0% to 2.2% of total combinations during the period) with favorable results depending on location (Table O-50). There were zero to one combination (0% to 2.2%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at any location. There were zero to two combinations (0% to 4.4%) with unfavorable results depending on location. For the 59.9°F adult migration pathogen virulence threshold, there were zero and one combination (0% to 2.2%) with favorable results depending on location. There were zero and five combinations (0% to 11.1%) with unfavorable results depending on location. These results suggest that there would be negative water temperature-related effects and negligible positive effects of Alternative 1 on steelhead adult upstream migration and holding.

Table O-50. Summary of Results for Water Temperature Analyses for Steelhead Adult Upstream Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
41°F–66.2°F RANGE FOR MINIMAL MIGRATION IMPAIRMENT							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	1 (2.2%)
Unfavorable	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	1 (2.2%)	1 (2.2%)	1 (2.2%)	0 (0.0%)	0 (0.0%)	3 (6.7%)	1 (2.2%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	1 (2.2%)
69.8°F UPPER LETHAL LIMIT TO ADULT MIGRANTS							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (4.4%)	1 (2.2%)	0 (0.0%)	1 (2.2%)	1 (2.2%)	0 (0.0%)	0 (0.0%)
59.9°F PATHOGEN VIRULENCE THRESHOLD FOR ADULT MIGRATION							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	3 (6.7%)	0 (0.0%)	0 (0.0%)	3 (6.7%)	3 (6.7%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	1 (2.2%)	4 (8.9%)	4 (8.9%)	4 (8.9%)	4 (8.9%)	6 (13.3%)	5 (11.1%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.2%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	0 (0.0%)
Unfavorable	5 (11.1%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)	2 (4.4%)	1 (2.2%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Removal of Sacramento River Pulse Flows

There may be adverse impacts of spring pulse flows on adult migration through decreased travel time.

Summary

There are expected adverse impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 1 in comparison with the No Action Alternative. Under Alternative 1, changes in flows are expected to have a negligible impact in the upper portions of the Sacramento River but may have adverse impacts during peak migration in September of critically dry water year types, in the lower Sacramento River below Wilkins Slough. Removal of the pulse flows component under Alternative 1 may increase travel time for adult migrants. Water temperatures above the pathogens and disease criteria increase in frequency in the lower Sacrament River at Hamilton City under Alternative 1 in comparison to the No Action Alternative. Water temperatures above the lethal limit that blocks migration also increase in frequency in the lower Sacramento River at Hamilton City under Alternative 1 in comparison to the No Action Alternative.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Similar to the section above for adult migration, a threshold of 3,250 cfs has been used to evaluate the potential for adverse effects (Long-term Operations 2019 EIS). Flows in the Sacramento River rarely drop below this level, and adults have not been observed to experience passage delays, crowding, or other adverse effects at this flow. Therefore, it represents a reasonable threshold for evaluating the potential for adverse effects on migrating and holding adults.

During the steelhead kelt emigration period, approximately February through June, CalSim 3 modeling of Sacramento River mean monthly flows do not go below the threshold of 3,250 cfs at Keswick Dam, RBDD, Wilkins Slough or Hamilton City under Alternative 1 and the No Action Alternative (Table O-14 through Table O-17). These results suggest flows are adequate for kelt emigration in the Sacramento River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F migration impairment limit during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 146 for Keswick Dam, Table 148 for Red Bluff Diversion Dam, and Table 150 for Hamilton City. Full results for the percent of months with water temperature above the 69.8°F lethal limit to kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 154 for Keswick Dam, Table 156 for Red Bluff Diversion Dam, and Table 158 for Hamilton City. Full results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 162 for Keswick Dam, Table 164 for Red Bluff Diversion Dam, Table 166 for Hamilton City.

Results for the three analyses are summarized in Table O-51. Table O-51as described in Section O.4.8.1 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 66.2°F migration impairment limit, there were zero to four month-water year type combinations (0% to 16.0% of total combinations during the period) with favorable results depending on location (Table O-51). There were no combinations (0%) with unfavorable results at all locations. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at all locations. There were no combinations (0%) with unfavorable results depending at all locations. For the 59.9°F adult migration pathogen virulence threshold, there were zero to 12 combinations (0% to 48.0%) with favorable results depending on location. There were no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 1 on steelhead kelt emigration.

Table O-51. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Kelt Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66.2°F MIGRATION IMPAIRMENT LIMIT							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	4 (16.0%)	1 (4.0%)	2 (8.0%)	2 (8.0%)	2 (8.0%)	1 (4.0%)	3 (12.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (8.0%)	1 (4.0%)
69.8°F UPPER LETHAL LIMIT TO ADULT MIGRANTS							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F PATHOGEN VIRULENCE THRESHOLD FOR ADULT MIGRATION							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	12 (48.0%)	10 (40.0%)	9 (36.0%)	7 (28.0%)	7 (28.0%)	5 (20.0%)	2 (8.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (8.0%)	2 (8.0%)
Hamilton City							
Favorable	2 (8.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	1 (4.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Removal of Sacramento River Pulse Flows

There may be adverse impacts of spring pulse flows on kelt emigration migration through increased travel time.

Summary

There are expected beneficial impacts of seasonal operations on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows are expected to be above the minimum flow to avoid crowding and passage delays from Keswick Dam to Hamilton City in the Sacramento River. Removal of the pulse flows component under Alternative 1 may increase travel time for kelt emigration. Water temperatures above the pathogens and disease criteria may decrease in frequency at RBDD and Hamilton City. Water temperatures above the migration impairment limit may decrease in frequency at Hamilton City.

O.4.10.2 Clear Creek

Spawning and Egg Incubation

In Clear Creek, the temporal distribution of redd count data shows spawning December through April, with peak spawning January (Schaefer et al. 2019; Provins and Chamberlain 2019a, 2019b, 2020). Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two-four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In Clear Creek, estimated incubation timing based on spawning is late-December through late-May.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 1, mean spawning WUA decreases in all water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean spawning WUA under Alternative 1 in comparison to the No Action Alternative. The largest reduction in mean spawning habitat is an 65.2% decrease in above normal water year types. On average across all water year types, there is a 63.3% reduction in mean spawning habitat under Alternative 1.

The mean values of spawning WUA by month are much lower under Alternative 1 compared to the other alternatives and the No Action Alternative, from December through March (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the four months, December has the highest expected WUA values.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that steelhead spawning habitat may decrease 15.8-28.4% January through March for Alternative 1 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The two spawning habitat analyses based on CalSim 3 simulated flows suggest that Alternative 1 may have an adverse effect, as steelhead spawning habitat may decrease on average by 75.5% across all water year types in Clear Creek when compared to the No Action Alternative, and that spawning habitat will likely decrease each month of the spawning period in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis* Table 138 for Clear Creek at Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 144 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 174 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-52. Table O-52, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 45°F to 55°F range for successful spawning, there were three month-water year type combinations (10.0% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable results below Whiskeytown Dam (Table O-52). For the 59.9°F adult pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 45°F to 52°F range for optimal egg incubation, there were four combinations (11.4%) with favorable results and no combinations (0%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be positive water temperature-related effects of Alternative 1 on steelhead spawning and egg incubation in Clear Creek.

Table O-52. Summary of Results for Water Temperature Analyses for Steelhead Spawning and Egg Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
45°F–55°F RANGE FOR SUCCESSFUL SPAWNING							
Below Whiskeytown Dam							
Favorable	3 (10.0%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)
Unfavorable	0 (0.0%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
45°F–52°F RANGE FOR OPTIMAL EGG INCUBATION							
Below Whiskeytown Dam							
Favorable	4 (11.4%)	1 (2.9%)	1 (2.9%)	1 (2.9%)	1 (2.9%)	1 (2.9%)	1 (2.9%)
Unfavorable	0 (0.0%)	1 (2.9%)	1 (2.9%)	1 (2.9%)	1 (2.9%)	3 (8.6%)	2 (5.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead spawning and egg incubation based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows may have a substantial impact on spawning habitat (75.5% decrease on average) across all water year types. Water temperatures outside of the successful spawning range and optimal egg incubation range may decrease in frequency in Clear Creek below Whiskeytown Dam.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in Clear Creek. The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station in lower Clear Creek indicates outmigration into the Sacramento River with median passage starting in November and ending in June, with peak passage between April and June (Schraml and Chamberlain 2019a, 2019b, 2020, 2021).

Potential Changes to Steelhead from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 1, mean fry rearing WUA increases in all water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 7.7% increase in critically dry water year types. There are no anticipated reductions in mean fry rearing WUA under Alternative 1 in comparison to the No Action Alternative.

The mean values of fry rearing WUA by month are slightly higher under Alternative 1 compared to the other alternatives and the No Action Alternative, from February through June (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The expected fry rearing WUA values are similar across all months.

The results of the fry rearing habitat analysis based on CalSim3 simulated flows suggest that Alternative 1 may have a minor (less than 8%) increase in estimated steelhead fry rearing habitat across all water year types in Clear Creek.

Juvenile Rearing Habitat Analyses

Under Alternative 1, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 1 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 45.3% decrease in below normal water year types. On average across all water year types, there is a 45% reduction in estimated juvenile rearing habitat under Alternative 1.

The mean values of juvenile rearing WUA by month are much lower under Alternative 1 compared to the other alternatives and the No Action Alternative, from July through December (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the six months, December has the highest expected juvenile rearing WUA values.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for steelhead in Clear Creek may decrease 31.3-50.8% January through December under Alternative 1 compared to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest decrease in estimated habitat may occur in June under Alternative 1 in comparison to the No Action Alternative.

The results of the two steelhead juvenile rearing habitat analyses based on CalSim3 simulated flows suggest that Alternative 1 may have a substantial adverse effect, as rearing habitat may decrease by 45% on average across all water year types in comparison to the No Action Alternative, and may decrease between 31.3-50.8% throughout the year on a monthly scale. The steelhead juvenile rearing WUA analysis in Attachment O.1, *Clear Creek Weighted Usable Area Analysis* analyzed the period between July and December, but some juveniles may rear year-round in Clear Creek, up to four years before emigration to the ocean. The largest decreases are expected in June during the juvenile rearing period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperature range year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 186 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 194 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 55°F upper limit of successful smoltification during January through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 202 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-53. Table O-53, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 66.2°F upper limit of optimum temperature range for juvenile steelhead growth, there were no month-water year type combinations (0% of total combinations during the period) with favorable results and one combination (1.7%) with unfavorable results below Whiskeytown Dam (Table O-53). For the 59.9°F juvenile pathogen virulence threshold, there were zero combinations (0%) with favorable results and one combination (1.7%) with unfavorable results below Whiskeytown Dam. For the 55°F upper limit of successful smoltification, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on steelhead juvenile rearing and emigration in Clear Creek.

Table O-53. Summary of Results for Water Temperature Analyses for Steelhead Juvenile Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66.2°F UPPER LIMIT OF OPTIMUM TEMPERATURE RANGE FOR JUVENILE STEELHEAD GROWTH, ASSUMING MAXIMUM RATION LEVELS							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F JUVENILE PATHOGEN VIRULENCE THRESHOLD							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
55°F UPPER LIMIT OF SUCCESSFUL SMOLTIFICATION							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be substantial adverse impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows may have a substantial decrease on fry and juvenile rearing habitat area. Water temperatures above the upper limit of optimum temperature range for growth may slightly increase in frequency in Clear Creek below Whiskeytown Dam. Water temperatures above the pathogens and disease criteria may slightly increase in frequency in Clear Creek below Whiskeytown Dam.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). In Clear Creek, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as August and throughout February (Killam 2022).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the August through February period of adult steelhead migration and holding in Clear Creek, the mean monthly flows under Alternative 1 will be reduced throughout the year which range from 45% in January in wet water year types, up to 86% in February during above normal water year types. Throughout the full simulation period, flows on average will range from 49-74% reduction. Reduced flows below 100 cfs throughout this period in Clear Creek may cause delays in migration and crowding for adult steelhead.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range for minimal migration impairment during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 116 for below Whiskeytown Dam. Results for the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 124 for below Whiskeytown Dam. Results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for adult migration and holding during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 32 for below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-54. Table O-54, as described in Section O.4.8.1reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 41°F to 66.2°F range for minimal migration impairment, there were no month-water year type combinations (0% of total combinations during the period) with favorable results and one combination (2.2%) with unfavorable results below Whiskeytown Dam (Table O-54). For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results and one combination (2.2%) with unfavorable results below Whiskeytown Dam. For the 59.9°F pathogen virulence threshold for adult migrants, there were no combinations (0%) with favorable results and one combination (2.2%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on steelhead adult upstream migration and holding in Clear Creek.

Table O-54. Summary of Results for Water Temperature Analyses for Steelhead Adult Upstream Migration and Holding in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
41°F–66.2°F RANGE FOR MINIMAL MIGRATION IMPAIRMENT							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
69.8°F UPPER LETHAL LIMIT TO ADULT MIGRANTS							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F PATHOGEN VIRULENCE THRESHOLD FOR ADULT MIGRATION							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are expected adverse impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 1 in comparison with the No Action Alternative. Under Alternative 1 compared to the No Action Alternative, reductions in Clear Creek flows throughout the year may cause crowding or delays in adult migration and holding. Water temperatures above all three temperature criteria slightly increase in frequency (less than 3%) in Clear Creek below Whiskeytown Dam under Alternative 1 in comparison to the No Action Alternative.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the February through June period of steelhead kelt emigration in Clear Creek, the mean monthly flows under Alternative 1 will be reduced throughout the year which range from 48% in March in wet water year types, up to 86% in February during above normal water year types. Throughout the full simulation period, flows on average will range from 64-84% reduction. Reduced flows below 100 cfs throughout this period in Clear Creek may cause delays in emigration and crowding for steelhead kelts.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F migration impairment limit during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 152 for below Whiskeytown Dam. Full results for the percent of months with water temperature above the 69.8°F lethal limit to kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 160 for below Whiskeytown Dam. Full results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 168 for below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-55. Table O-55, as described in Section O.4.8.1 the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 66.2°F kelt migration impairment limit, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-55). For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F pathogen virulence threshold for adult migration, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on steelhead kelt migration in Clear Creek.

Table O-55. Summary of Results for Water Temperature Analyses for Steelhead Kelt Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66.2°F MIGRATION IMPAIRMENT LIMIT							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
69.8°F UPPER LETHAL LIMIT TO ADULT MIGRANTS							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F PATHOGEN VIRULENCE THRESHOLD FOR ADULT MIGRATION							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are expected adverse impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 1 in comparison with the No Action Alternative. Under Alternative 1 compared to the No Action Alternative, substantial reductions in Clear Creek flows throughout the year may cause crowding or delays in kelt emigration. Water temperatures above the three temperature criteria for kelts are not anticipated to change in frequency in Clear Creek below Whiskeytown Dam under Alternative 1 in comparison to the No Action Alternative.

O.4.10.3 Lower American River

Spawning and Egg Incubation

In the lower American River, redd surveys have reported spawning January through mid-April, with peak spawning in February (Sweeney et al. 2021). The median months of spawning from 2002-2021 were from January through March. Redd surveys on the lower American River do not occur until the first week of January, and there are reports from the Sacramento Water Forum (2015) that indicate spawning starts in late December. Therefore, the timing window of spawning on the lower American River was analyzed from late December until March.

Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). On the lower American River, egg incubation starts in late December and ends in late May, with peak incubation between February and April (Hannon pers. comm. 2023; Sacramento Water Forum 2015).

Potential Changes to Steelhead from Seasonal Operations

<u>Spawning Habitat—Flow Analyses</u>

Under Alternative 1, lower American River steelhead mean spawning WUA is highest in critically dry water years and steadily falls with wetter year types (Attachment M.3, *American River Weighted Usable Area Analysis*). This pattern of variation occurs because streamflows during the January through March spawning season of steelhead rise from dry to wetter water year types (Table O-25). The lower American River steelhead spawning WUA curve peaks at about 2,000 cfs (Attachment M.3, *American River Weighted Usable Area Analysis*) and flows under Alternative 1 are consistently well above this level in the wetter water years. February flows are especially high in all but critically dry water years and consequently February shows the lowest spawning WUA for all alternatives (Attachment M.3, *American River Weighted Usable Area Analysis*). Mean spawning WUA is lower under Alternative 1 than under the No Action Alternative for all water year types, ranging from 2.4% lower in wet water years to 12.2% lower in critically dry water years and 13.3% lower in dry water years (Attachment M.3, *American River Weighted Usable Area Analysis*). For all three months of the steelhead spawning season, median spawning WUA under Alternative 1 is substantially lower than that under the No Action Alternative (Attachment M.3, *American River Weighted Usable Area Analysis*).

The results of the SIT LCM model for Alternative 1 are generally the same as those described above, showing substantial reductions in spawning WUA in comparison to the results for the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

Overall, the results indicate that mean spawning WUA for steelhead is lower under Alternative 1 than under the No Action Alternative. Reductions are especially large in dry and critically dry water year types.

Redd Dewatering Analysis

The results of the analysis for redd dewatering potential for lower American River steelhead indicate that redd dewatering is much greater in wetter water years than in drier water years for Alternative 1 (Attachment M.1, *American River Redd Dewatering Analysis*). This difference reflects the greater frequency of larger flow fluctuations in wetter years. Redd dewatering potential is consistently higher under Alternative 1 than under the No Action Alternative, and the percent difference greatly increases from wetter to drier water years (Attachment M.1, *American River Redd Dewatering Analysis*). Some of the differences are very large, including a maximum of 301.2% higher redd dewatering under Alternative 1 in critically dry water years. In absolute terms the increase is from 4.6% to 18.5%, which is still large. For the individual months of steelhead spawning in the lower American River, redd dewatering potential is highest and most variable in February for both the No Action Alternative and Alternative 1, but the median redd dewatering is much higher for Alternative 1 (Attachment M.1, *American River Redd Dewatering Analysis*). Redd dewatering is high in February because flows during the two-month incubation period following February spawning exhibit greater declines than those for January and March (Table O-25).

Overall, the results indicate that Alternative 1 produces increases in redd dewatering potential of steelhead relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 20 for Hazel Avenue and Table 22 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold for spawning adults during December through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 24 for Hazel Avenue and Table 26 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 40 for Hazel Avenue and Table 42 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold during December through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 44 for Hazel Avenue and Table 46 for Watt Avenue.

Results for the four analyses are summarized in Table O-56. Table O-56 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 45°F to 55°F range for successful spawning under Alternative 1, there were zero combinations (0%) with favorable results at both Hazel and Watt Avenue (Table O-56). There were one and four month-water year type combinations (5% and 20.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F spawning pathogen virulence threshold, there were zero month-water year type combinations (0%) with favorable results at both Hazel and Watt Avenue. There were zero and two combinations (0% and 10.0% respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 45°F to 52°F range for optimal egg incubation analysis, there were two and zero month-water year type combinations (6.7% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. Similarly, there were two and zero month-water year type combinations (6.7% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold analysis, there were zero to one month-water year type combinations (0% and 3.3% respectively) with favorable results at Hazel Avenue and Watts Avenue, respectively. There were two and five month-water year type combinations (6.7% and 16.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be some negative effects (5%–20% unfavorable) and some positive effects (3.3%–6.7% favorable) of Alternative 1 on steelhead spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Table O-56. Summary of Results for Water Temperature Analyses for Steelhead Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
45°F–55°F RANGE FOR SUCCESSFUL SPAWNING							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (15.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)
Unfavorable	4 (20.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)
59.9°F SPAWNING PATHOGEN VIRULENCE THRESHOLD							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
45°F–52°F RANGE FOR OPTIMAL EGG INCUBATION							
Hazel Avenue							
Favorable	2 (6.7%)	1 (3.3%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	2 (6.7%)	1 (3.3%)
Unfavorable	2 (6.7%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	4 (13.3%)	2 (6.7%)
Watt Avenue							
Favorable	0 (0.0%)	2 (6.7%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)
59.9°F FRY PATHOGEN VIRULENCE THRESHOLD							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)
Unfavorable	2 (6.7%)	1 (3.3%)	0 (0.0%)	2 (6.7%)	2 (6.7%)	2 (6.7%)	1 (3.3%)
Watt Avenue							
Favorable	1 (3.3%)	1 (3.3%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	2 (6.7%)	0 (0.0%)
Unfavorable	5 (16.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be substantial adverse impacts of seasonal operations on steelhead spawning and egg incubation in the lower American River based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows may decrease spawning habitat area and may increase redd dewatering potential during drier water year types. Water temperatures above the successful spawning criteria and fry pathogen virulence threshold increase in frequency in the lower American River at Watt Ave.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Yearling rearing is year-round in the lower American River. Young of the year fry rearing is from February through May (Sacramento Water Forum 2015). The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station in the lower American River indicates outmigration into the Sacramento River with median passage starting in January and ending in May, with peak passage between March and May (Day 2022a).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During steelhead rearing in the lower American River, the mean monthly flows throughout the late summer and fall under Alternative 1 are generally reduced in comparison to the No Action Alternative, which may impact juveniles rearing habitat during critically dry water year types (Table O-26 and Table O-25). Reductions under Alternative 1 are anticipated in November, May, and September of critically dry years when flows are below 1,000 cfs. The greatest increase in flows under Alternative 1 occur in April of a critically dry water year type (149% in the lower American River at H St) which may benefit rearing, particularly fry rearing. The greatest reduction occurs in September of a dry water year type (57% in the lower American River at H St).

The CalSim3 simulated flow results suggest that changes in flow in the lower American River under Alternative 1 compared to the No Action Alternative may have an adverse and beneficial impact on both juvenile and fry rearing habitat during critically dry water year types. There are no reliable estimates for steelhead juvenile rearing habitat using weighted usable area analyses. USFWS 1985 derives spawning and rearing weighted usable area on fall-run Chinook salmon, but this study did not assess steelhead and has not been peer reviewed.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 48 for Hazel Avenue and Table 50 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F rearing and outmigration pathogen virulence threshold year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 52 for Hazel Avenue and Table 54 for Watt Avenue. Full results of the analysis assessing water temperatures above the percent of months with water temperature above the 55°F limit of successful smoltification during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 56 for Hazel Avenue and Table 58 for Watt Avenue.

Results for the three analyses are summarized in Table O-57. Table O-57 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels under Alternative 1, there were six and one month-water year type combinations (10% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-57). There were one and five month-water year type combinations (1.7% and 8.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F juvenile pathogen virulence threshold, there were zero and one month-water year type combinations (0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were five month-water year type combinations (8.3%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 55°F limit of

successful smoltification, there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue. There were two and three month-water year type combinations (8% and 12%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that Alternative 1 would have positive (1.7%–10% favorable) and negative (1.7%–12% unfavorable) water temperature-related effects to steelhead juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Table O-57. Summary of Results for Water Temperature Analyses for Steelhead Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66.2°F UPPER LIMIT OF OPTIMUM TEMPERATURES FOR JUVENILE STEELHEAD GROWTH, ASSUMING MAXIMUM RATION LEVELS							
Hazel Avenue							
Favorable	6 (10.0%)	2 (3.3%)	4 (6.7%)	3 (5.0%)	1 (1.7%)	1 (1.7%)	4 (6.7%)
Unfavorable	1 (1.7%)	1 (1.7%)	1 (1.7%)	3 (5.0%)	3 (5.0%)	3 (5.0%)	2 (3.3%)
Watt Avenue							
Favorable	1 (1.7%)	1 (1.7%)	1 (1.7%)	2 (3.3%)	1 (1.7%)	2 (3.3%)	1 (1.7%)
Unfavorable	5 (8.3%)	2 (3.3%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	6 (10.0%)	4 (6.7%)
59.9°F JUVENILE PATHOGEN VIRULENCE THRESHOLD							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)
Unfavorable	5 (8.3%)	1 (1.7%)	0 (0.0%)	2 (3.3%)	2 (3.3%)	6 (10.0%)	1 (1.7%)
Watt Avenue							
Favorable	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	2 (3.3%)	3 (5.0%)	0 (0.0%)
Unfavorable	5 (8.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	1 (1.7%)
55°F LIMIT OF SUCCESSFUL SMOLTIFICATION							
Hazel Avenue							
Favorable	0 (0.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (8.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)
Unfavorable	3 (12.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration in the lower American River based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flow during critically dry water years may result in a decrease on fry and juvenile rearing habitat area when flows are already low. Water temperatures above the upper limit of optimum temperature range for growth are expected to increase in frequency in the lower American River at Watt Ave and decrease in frequency at Hazel Ave. Water temperatures above the pathogens and disease criteria and smoltification criteria are expected increase in frequency in both locations in the lower American River.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). In the lower American River, adult steelhead migration may occur as early as July and through early April, with peak abundance in January and February (Sacramento Water Forum 2015; Hallock 1989; Hallock et al. 1957).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Flows in the lower American River below Nimbus Dam will be lower under Alternative 1 compared to the No Action Alternative during the initial months of steelhead adult migration and holding, but are expected to be similar during peak migration (Table O-25 and Table O-26). Peak steelhead adult migration in the lower American River occurs between January and February (Sacramento Water Forum 2015), when flows are expected to increase in above normal, below normal, and dry water year types under Alternative 1. There may be reductions in flow under Alternative 1 in January of critically dry water year types, and flows are expected to be above 1,000 cfs during this period. September has the greatest reductions in flow throughout the migration period, with a 57% reduction in dry water year types and 36% reduction in critically dry water year types. Flows in September of these water year types are expected to be below 1,000 cfs under Alternative 1 but are likely still adequate for adult migration. No adult migration flow thresholds have been established for the lower American River. These results of the CalSim3 simulated flows suggest that there may be a negligible effect of Alternative 1 compared to the No Action Alternative on steelhead adult migration and holding in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range of minimal migration impairment for adult steelhead during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 8 for Hazel Avenue and Table 10 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 12 for Hazel Avenue and Table 14 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult upstream migration and holding pathogen virulence threshold during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 16 for Hazel Avenue and Table 18 for Watt Avenue.

Results for the three analyses are summarized in Table O-58. Table O-58 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 41°F to 66.2°F range of minimal migration impairment for adult steelhead under Alternative 1, there were five and zero month-water year type combinations (10% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-58). There were one and four month-water year type combinations (2.0% and 8.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there were 3 and 2 month-water combinations (6.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and four month-water year type combinations (4.0% and 8.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F adult upstream migration and holding pathogen virulence threshold, there were zero and one month-water year type combinations (0.0% and 2.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and five month-water year type combinations (4.0% and 10.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that Alternative 1 would have positive (2%–10% favorable) and negative (2%–10% unfavorable) water temperature-related effects to steelhead adult upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue.

Table O-58. Summary of Results for Water Temperature Analyses for Adult Steelhead Upstream Migration and Holding for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
41°F–66.2°F RANGE OF MINIMAL MIGRATION IMPAIRMENT							
Hazel Avenue							
Favorable	5 (10.0%)	2 (4.0%)	4 (8.0%)	3 (6.0%)	1 (2.0%)	0 (0.0%)	4 (8.0%)
Unfavorable	1 (2.0%)	0 (0.0%)	1 (2.0%)	1 (2.0%)	2 (4.0%)	3 (6.0%)	2 (4.0%)
Watt Avenue							
Favorable	0 (0.0%)	1 (2.0%)	1 (2.0%)	2 (4.0%)	1 (2.0%)	2 (4.0%)	1 (2.0%)
Unfavorable	4 (8.0%)	1 (2.0%)	1 (2.0%)	0 (0.0%)	0 (0.0%)	2 (4.0%)	1 (2.0%)
69.8°F UPPER LETHAL LIMIT TO ADULT MIGRANTS							
Hazel Avenue							
Favorable	3 (6.0%)	2 (4.0%)	1 (2.0%)	1 (2.0%)	2 (4.0%)	2 (4.0%)	1 (2.0%)
Unfavorable	2 (4.0%)	0 (0.0%)	1 (2.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.0%)
Watt Avenue							
Favorable	2 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.0%)	2 (4.0%)	1 (2.0%)
Unfavorable	4 (8.0%)	3 (6.0%)	2 (4.0%)	3 (6.0%)	4 (8.0%)	4 (8.0%)	3 (6.0%)
59.9°F ADULT UPSTREAM MIGRATION AND HOLDING PATHOGEN VIRULENCE THRESHOLD							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (6.0%)	0 (0.0%)
Watt Avenue							
Favorable	1 (2.0%)	1 (2.0%)	1 (2.0%)	1 (2.0%)	2 (4.0%)	3 (6.0%)	0 (0.0%)
Unfavorable	5 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.0%)	1 (2.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are expected adverse impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 1 in comparison with the No Action Alternative. Under Alternative 1 compared to the No Action Alternative, reductions in lower American River flows in September of dry and critically dry water year types may cause crowding and delays for adult migrants, but there are likely adequate flows during peak adult migration and holding. Water temperatures above all three temperature criteria both increase in frequency and decrease in frequency (2-10%) in the lower American River under Alternative 1 in comparison to the No Action Alternative, depending on the location (Hazel Ave or Watt Ave). Water temperatures above the lethal limit that blocks migration are expected to increase in frequency more often at Watt Avenue but decrease in frequency more often at Hazel Avenue.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Flows in the lower American River below Nimbus Dam will be on higher on average under Alternative 1 compared to the No Action Alternative most months of steelhead kelt emigration period (Table O-25 and Table O-26). Peak kelt emigration is likely March through May when flows are expected to be adequate for emigration under Alternative 1. There are expected reductions (12-17%) in flow in March of below normal and dry water year types under Alternative 1. In April of critically dry years, flows may substantially increase under Alternative 1 (133-149%). These results of the CalSim3 simulated flows suggest that there may be both minor adverse and minor beneficial effects of Alternative 1 compared to the No Action Alternative to kelt emigration, but flows are likely adequate for kelt emigration.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F limit of migration impairment for steelhead kelt emigration during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 28 for Hazel Avenue and Table 30 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F lethal limit for steelhead kelt emigration during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 32 for Hazel Avenue and Table 34 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F kelt emigration pathogen virulence threshold during February through June are presented in Attachment M.2,

American River Water Temperature Analysis, Table 36 for Hazel Avenue and Table 38 for Watt Avenue.

Results for the three analyses are summarized in Table O-59. Table O-59 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F limit of migration impairment for steelhead kelt emigration under Alternative 1, there was one month-water year type combinations (4.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-59). There were zero and three month-water year type combinations (0.0% and 12.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F lethal limit for steelhead kelt emigration there were zero and two month-water year type combinations (0.0% and 8.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F kelt emigration pathogen virulence threshold there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were three and five month-water year type combinations (12.0% and 20.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be positive (4%–8% favorable) and negative (4%–20% unfavorable) water temperature-related effects to steelhead kelt emigration in the lower American River at Hazel Avenue and Watt Avenue.

Table O-59. Summary of Results for Water Temperature Analyses for Steelhead Kelt Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66.2°F LIMIT OF MIGRATION IMPAIRMENT							
Hazel Avenue							
Favorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	1 (4.0%)	0 (0.0%)	2 (8.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	3 (12.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (16.0%)	3 (12.0%)
69.8°F LETHAL TO ADULT MIGRATION							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Watt Avenue							
Favorable	2 (8.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	4 (16.0%)	0 (0.0%)
59.9°F PATHOGEN VIRULENCE THRESHOLD							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Unfavorable	3 (12.0%)	1 (4.0%)	0 (0.0%)	2 (8.0%)	2 (8.0%)	3 (12.0%)	1 (4.0%)
Watt Avenue							
Favorable	1 (4.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	2 (8.0%)	0 (0.0%)
Unfavorable	5 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be adverse impacts of seasonal operations on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 1 in comparison with the No Action Alternative. Under Alternative 1 compared to the No Action Alternative, flows are likely adequate for kelt emigration. In the lower American River at Watt Avenue, water temperatures are more favorable under the migration lethal threshold (8% favorable, 4% unfavorable) but less favorable for the pathogens and disease criteria (4% favorable, 20% unfavorable).

O.4.10.4 Bay-Delta

Juvenile Rearing and Emigration

While juvenile steelhead can be found in all waterways of the Delta, they are seen more frequently in the main channels to their natal river systems (National Marine Fisheries Service 2009a). The San Francisco Estuary is used as a short-term outmigration corridor for juvenile steelhead but the propensity of rearing in the Delta is currently unknown (Hayes and Kocik 2014, Chapman et al. 2015, Buchanan et al. 2021). The USFWS monitoring programs (Sacramento beach seines, Sacramento trawl, and Knight's Landing RST) indicate outmigration timing from the Sacramento River with first median passage in January and last median passage in May (Columbia Basin Research, University of Washington 2024). Outmigration from the San Joaquin River is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024).

Potential Changes to Steelhead from Seasonal Operations

Differences in hydrology in the Delta under Alternative 1 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using several quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions.

Zone of Influence

Differences in hydrology under Alternative 1 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. These possible differences were evaluated using DSM2-HYDRO outputs. For a detailed description of how flows under Alternative 1 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 1, Sacramento River winter-run Chinook salmon ESU (Section O.4.8.2, *Zone of Influence*).

Flow into Junctions

Alternative 1 compared with the No Action Alternative may have effects on the flow into the Head of Old River and CVP junctions due to differences in flow routing. These possible differences were evaluated using DSM2-HYDRO outputs. For a detailed description of how flows under Alternative 1 may impact the flow at Head of Old River and CVP, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2, *Zone of Influence*).

Summary

Alternative 1 relative to the No Action Alternative is expected to influence flow into the Head of Old River and CVP junctions. Under Alternative 1, possibly less flow into CVP under OMR -2,000 and -5,000; possibly less flow into HOR under all OMR groups. Impacts of pumping under both Alternative 1 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Steelhead

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on juvenile steelhead entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using two quantitative models: Salvage Density and Negative Binomial.

Salvage Density and Negative Binomial

Predictions from the salvage density and negative binomial loss models for steelhead include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of steelhead at SWP Banks Pumping Plant for all the months December through April of all water year types Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 95% greater for the below normal water year type (Table O-60). Predicted average monthly loss of steelhead at CVP Jones Pumping Plant for

all the months October through April Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 21% greater, in the critically water year type (Table O-61). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Table O-60. Predicted Average Monthly Loss of Steelhead at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	377	617 (64%)	372 (-1%)	372 (-1%)	372 (-1%)	373 (-1%)	222 (-41%)	351 (-7%)	4: Dec–March
Above Normal	300	567 (89%)	293 (-2%)	291 (-3%)	288 (-4%)	287 (-4%)	198 (-34%)	269 (-10%)	4: Dec–March
Below Normal	81	157 (95%)	78 (-3%)	78 (-3%)	77 (-4%)	76 (-5%)	68 (-15%)	78 (-3%)	5: Dec–April
Dry	359	503 (40%)	360 (0%)	358 (0%)	351 (-2%)	340 (-5%)	182 (-49%)	312 (-13%)	2: Dec–Jan.
Critically Dry	96	138 (43%)	98 (2%)	92 (-5%)	88 (-8%)	89 (-8%)	76 (-21%)	95 (-1%)	5: Dec–April

Table O-61. Predicted Average Monthly Loss of Steelhead at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	58	61 (6%)	57 (-1%)	57 (-1%)	57 (-1%)	58 (-1%)	43 (-25%)	55 (-5%)	5: Oct–Feb
Above Normal	49	58 (18%)	52 (6%)	52 (6%)	52 (7%)	52 (7%)	26 (-47%)	50 (2%)	5: Oct–Feb
Below Normal	14	17 (17%)	14 (-3%)	14 (-3%)	14 (-4%)	14 (-4%)	7 (-53%)	14 (-2%)	5: Dec–April
Dry	42	48 (14%)	43 (3%)	42 (0%)	41 (-1%)	41 (-1%)	18 (-58%)	42 (-1%)	2: Dec–Jan
Critically Dry	29	35 (21%)	27 (-5%)	29 (1%)	30 (4%)	30 (4%)	15 (-47%)	29 (2%)	4: Dec–March

Predicted average monthly salvage of juvenile steelhead at the Delta fish collection facilities for the months of December through June under Alternative 1 was greater than predicted loss under the No Action Alternative, up to 411% greater for the dry water year types (Table O-62). For

detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*, Table 8.

Table O-62. Predicted Average Monthly Salvage of Juvenile Steelhead at the Delta Fish Collection Facilities by Water Year Type, December–June

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	3145	5428 (73%)	4287 (36%)	4286 (36%)	3917 (25%)	3844 (22%)	1024 (-67%)	4375 (39%)
Above Normal	921	3909 (324%)	1298 (41%)	1248 (35%)	947 (3%)	915 (-1%)	948 (3%)	1478 (60%)
Below Normal	718	2857 (298%)	838 (17%)	832 (16%)	679 (-5%)	680 (-5%)	620 (-14%)	871 (21%)
Dry	339	1732 (411%)	342 (1%)	342 (1%)	277 (-18%)	278 (-18%)	278 (-18%)	401 (18%)
Critically Dry	218	632 (190%)	209 (-4%)	194 (-11%)	190 (-13%)	191 (-12%)	120 (-45%)	253 (16%)

Summary

The results of the two entrainment models suggest adverse impacts of flow under Alternative 1 compared to the No Action Alternative with increases in entrainment. Alternative 1 relative to the No Action Alternative is expected to have substantial increases (73-411%) in steelhead loss in all water year types in the Delta at both fish facilities under the Negative Binomial model due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have increases (6-95%) in steelhead loss across all water year types in the Delta at both fish facilities under the Salvage Density model due to differences in flow.

Potential Changes to Routing and Through Delta Survival of Steelhead

ECO-PTM

Differences in flows under Alternative 1 compared with the No Action Alternative may have effects on routing to Interior Delta via Georgiana Slough in the Delta and through Delta survival. These differences were evaluated using ECO-PTM. For a detailed description of how flows under Alternative 1 may impact steelhead routing and survival, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2).

Summary

Alternative 1 relative to the No Action Alternative using ECO-PTM suggests a beneficial impact due to differences in flow with a smaller proportion routed to Interior Delta between December and March, particularly in OMR bins more negative than -5,500.

O.4.10.5 San Joaquin River

Juvenile Emigration

The San Joaquin River is primarily documented as an outmigration corridor for juvenile steelhead (Buchanan et al. 2021). Outmigration from the San Joaquin River into the Delta is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024). RSTs in the lower Stanislaus River, a tributary to the San Joaquin River, suggests juvenile emigration into the San Joan Joaquin River starts in January and ends in June (Day 2022b).

Potential Changes to Steelhead from Seasonal Operations

Changes in flows from seasonal operations under Alternative 1 compared to the No Action Alternative may have a negligible effect on juvenile steelhead in the San Joaquin River. During the evaluated months in the juvenile emigration period, CalSim 3 estimates of mean monthly flows at Vernalis would generally be similar or increase under Alternative 1 compared to the No Action Alternative (Table O-29). Throughout the full simulation period, average flows will range from 3,664 to 6,553 cfs under Alternative 1.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on juvenile steelhead in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile emigration period (Figure O-16).

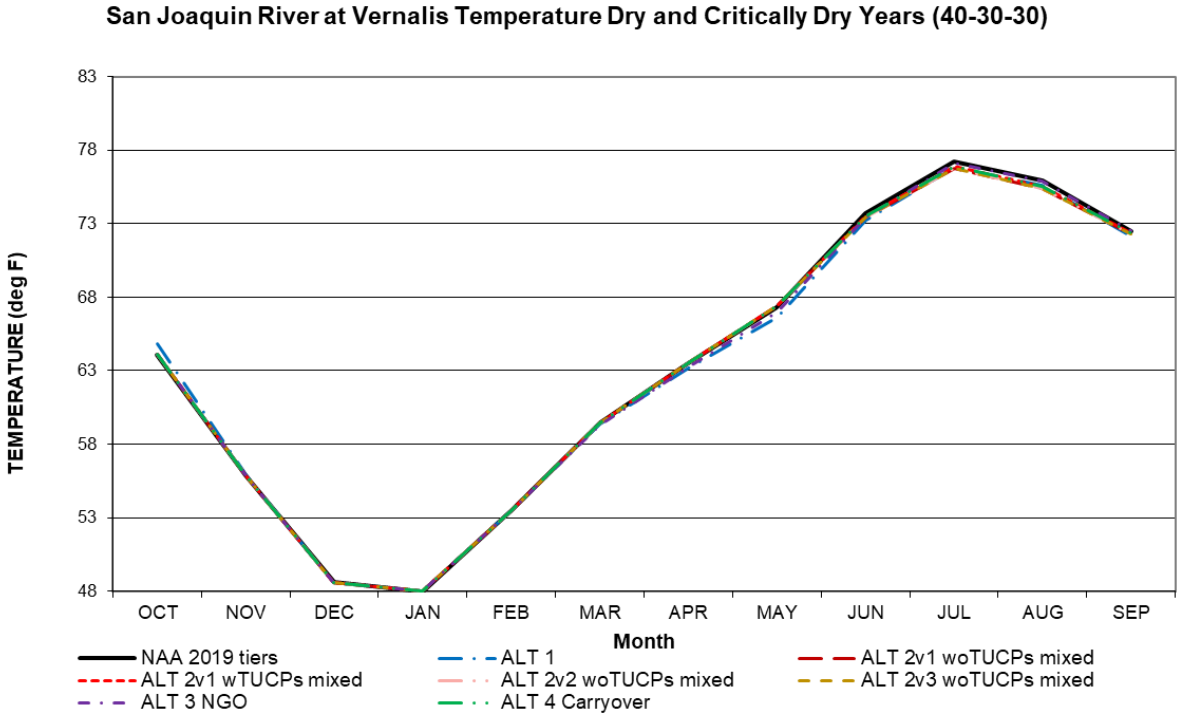


Figure O-16. San Joaquin River at Vernalis HEC-5Q Simulated Water Temperatures under the No Action Alternative and Alternatives 1-4, October through September

Summary

There are likely negligible impacts of seasonal operations on juvenile steelhead in the San Joaquin River based on analyses of simulated flows and water temperature under Alternative 1 in comparison with the No Action Alternative.

Adult Upstream Migration and Holding

Steelhead/rainbow trout of anadromous parentage occur at low numbers in all three major San Joaquin River tributaries. These tributaries have a higher percentage of resident rainbow trout compared to the Sacramento River and its tributaries (Zimmerman et al. 2009). Estimates of migrating adults in the San Joaquin River are made from the CDFW angler report cards and suggest that migration starts in July, peaks in December and January, and ends in March (California Department of Fish and Wildlife 2007).

Potential Changes to Steelhead from Seasonal Operations

Changes in flows from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible to minor beneficial effect on adult steelhead migration and holding in the San Joaquin River. During the evaluated months in the adult migration period, CalSim 3 estimates of mean monthly flows at Vernalis would decrease in October but are similar or increase all other months of the migration period under Alternative 1 compared to the No Action Alternative (Table O-29). Throughout the full simulation period, average flows will range from 1,977 to 6,553 cfs under Alternative 1.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible effect on adult steelhead migration and holding in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the adult migration period (Figure O-16).

Summary

There are likely negligible to minor beneficial impacts of seasonal operations on adult steelhead migration and holding in the San Joaquin River based on analyses of simulated flows and water temperature under Alternative 1 in comparison with the No Action Alternative.

O.4.10.6 Stanislaus River

Spawning and Egg Incubation

Data on steelhead spawning in the Stanislaus River is limited, but adults appear to spawn primarily from January to April. In 2021, as part of the reasonable and prudent measure to accelerate steelhead monitoring and research in the NMFS (2019) Biological Opinion, CDFW initiated the Stanislaus River Life Cycle Monitoring Program. Based on the initial redd survey report, which had a late start due to COVID-19 restrictions, spawning appears to start in February and last until April (Kok and Keller 2023). Although few steelhead spawning surveys have been conducted in the Stanislaus River, spawning *O. mykiss* has been documented upstream of the Highway 120 Bridge in Oakdale, between Goodwin Dam and the Oakdale Recreation Area.

Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In the Stanislaus River, timing can only be estimated and would be January through late May.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

The spawning WUA results for Alternative 1 show a consistent variation in mean spawning WUA with water year type, where the mean spawning WUA steadily increases from wet to critically dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the shape of the steelhead spawning WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show reduced WUA with increased flow, except at the lowest and highest flows (less than about 200 cfs and greater than about 800 cfs, respectively). CalSim 3 mean monthly flows below Goodwin Dam, which is immediately upstream of the WUA study reach, are 200 cfs or above in all water year types except in October, with flow consistently increasing from critically dry to wet water years during all months of the December through April steelhead spawning period, except December (Table O-27). All the mean spawning WUA estimates for Alternative 1 are below those for the No Action Alternative in all water year types, ranging from 6.0% lower in below normal water years to 21.5% lower in critically dry years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The lower mean spawning WUAs under Alternative 1 result from higher flows for Alternative 1 during December through April, especially in the drier water year types, (Table O-27). In the wetter year types, the flows are generally over 800 cfs, which is the point in most of the spawning WUA curves where WUA varies little with flow (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For all months except April, median spawning WUA under Alternative 1 is well below that of the No Action Alternative (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Spawning WUA for all the alternatives is much lower in April than in the other months. This reflects the higher mean in the drier water year types during April (Table O-27).

The results of the SIT LCM model for Alternative 1 are generally the same as those described above for spawning WUA, showing substantial reductions in spawning habitat in comparison to the results for the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

Overall, the results indicate that mean spawning WUA for steelhead is lower under Alternative 1 than under the No Action Alternative. This lower WUA results from higher flows under Alternative 1, especially in drier water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 16 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold for spawning adults during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 18 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water

temperature outside the 45°F to 52°F range for optimal egg incubation during December through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 32 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 54°F index value for egg incubation during December through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis,* Table 34 Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during December through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 36 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-63. Table O-63 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 45°F to 55°F range for successful spawning under Alternative 1, there were five month-water year type combinations (16%) with favorable results and one month-water year type combination (3.3%) with unfavorable results at Orange Blossom Bridge (Table O-63). For the 59.9°F spawning pathogen virulence threshold, there were zero month-water year type combinations (0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 45°F to 52°F range for optimal egg incubation analysis, there was one month-water year type combination (2.5%) with favorable results and zero month-water year type combinations (0%) with unfavorable results at Orange Blossom Bridge. For the 59.9°F fry pathogen virulence threshold analysis, there was one month-water year type combinations (2.5%) with favorable and unfavorable results at Orange Blossom Bridge. These results suggest that Alternative 1 would have positive effects on steelhead spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Table O-63. Summary of Results for Water Temperature Analyses for Steelhead Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
45°F–55°F RANGE FOR SUCCESSFUL SPAWNING							
Orange Blossom Bridge							
Favorable	5 (16.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (10.0%)	0 (0.0%)
Unfavorable	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	0 (0.0%)	1 (3.3%)
59.9°F SPAWNING PATHOGEN VIRULENCE THRESHOLD							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
45°F–52°F RANGE FOR OPTIMAL EGG INCUBATION							
Orange Blossom Bridge							
Favorable	1 (2.5%)	1 (2.5%)	1 (2.5%)	1 (2.5%)	1 (2.5%)	4 (10.0%)	1 (2.5%)
Unfavorable	0 (0.0%)	2 (5.0%)	2 (5.0%)	2 (5.0%)	2 (5.0%)	2 (5.0%)	2 (5.0%)
59.9°F FRY PATHOGEN VIRULENCE THRESHOLD							
Orange Blossom Bridge							
Favorable	1 (2.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)
Unfavorable	1 (2.5%)	1 (2.5%)	1 (2.5%)	1 (2.5%)	1 (2.5%)	0 (0.0%)	1 (2.5%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are expected minor to moderate adverse and beneficial impacts of seasonal operations on steelhead spawning and egg incubation in the Stanislaus River based on analyses of simulated flows and water temperature under Alternative 1 compared to the No Action Alternative. Under Alternative 1, changes in flows are expected to have a minor to moderate decrease in spawning habitat area depending on the water year type. Water temperatures outside the successful spawning range and egg incubation range are expected to decrease in frequency the Stanislaus River at Orange Blossom Bridge.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in the Stanislaus River. The timing of juvenile outmigration depends on the watershed and water year. RSTs in the lower Stanislaus River suggests juvenile emigration into the San Joan Joaquin River starts in January and ends in June (Day 2022b).

Potential Changes to Steelhead from Seasonal Operations

Rearing Habitat—WUA Flow Analyses

The results for mean fry rearing WUA under Alternative 1 for the different water year types show small but consistent reductions in WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the steelhead fry WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show moderately reduced WUA with increased flow, especially in Orange Blossom Bridge and Riverbank reaches, which are the longest segments. Mean fry rearing WUA under Alternative 1 is similar to that for the No Action Alternative in all water year types,

ranging from 3.4% lower in dry water years to 2.0% higher in wet water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fry rearing period, fry rearing WUA is lower under Alternative 1 than under the No Action Alternative in April and May and is slightly higher in March and June (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results for juvenile rearing WUA under Alternative 1 show a minor increase in mean rearing WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in juvenile rearing WUA between Alternative 1 and the No Action Alternative are small, ranging from 2.8% lower for critically dry water years to 3.0% higher for wet years. Juveniles rear year-round and mean juvenile rearing WUA is highest in April and May (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The SIT LCM model provides rearing habitat results for all juveniles, not separating out the fry stage from older juveniles. The instream juvenile rearing habitat results for Alternative 1 are very different from those described above for juvenile rearing WUA, showing substantial reductions in rearing habitat acreages from the No Action Alternative in all months, ranging from 76.9% lower in June to 35.3% lower in December (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). These differences in results from the different analyses of rearing habitat may be related to differences in how the habitat results from the different juvenile rearing reaches were combined in the analyses.

Overall, the rearing WUA results indicate that mean fry and juvenile rearing WUA for steelhead is largely similar under Alternative 1 to means under the No Action Alternative. However, the SIT model results show very large reductions in juvenile rearing habitat for Alternative 1 relative to the No Action Alternative.

Rearing Habitat—ASH Flow Analyses

The results of the Area of Suitable Habitat (ASH) analysis for fry and juvenile rearing are different from the rearing WUA results described above with respect to how ASH varies with water year type. The mean ASH estimates vary more strongly with water year type for both fry and juvenile steelhead, consistently increasing from critically dry to wet years. This pattern of variation reflects the overall relationship between flow and ASH for both life stages determined from modeling and field studies (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in fry and juvenile ASH between Alternative 1 and the No Action Alternative are small, which is consistent with the results of the rearing WUA analyses. For fry rearing, the differences range from 1.0% lower for wet water years and 4.8% higher for critically dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For juvenile rearing, the differences range from 1.6% lower for below normal water years and 3.4% higher for dry water years. For all months of the fry rearing period, the median fry rearing ASH is consistently higher under Alternative 1 than under the No Action Alternative, while for all months of the juvenile rearing period, the median juvenile rearing ASH is higher or similar under Alternative 1 relative to the No Action Alternative, except for much lower ASH under Alternative 1 in October (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that mean rearing ASH for fry and juvenile steelhead is largely similar under Alternative 1 to means under the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimal growth without food limitation year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 38 for Orange Blossom Bridge and Table 40 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 42 for Orange Blossom Bridge and Table 44 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperatures above the 55°F limit of successful smoltification during January through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 48 for Orange Blossom Bridge and Table 50 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-64. Table O-64, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F upper limit of optimal growth without food limitation under Alternative 1, there were zero and three month-water year type combinations (0.0% and 5.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-64). There were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 59.9°F juvenile pathogen virulence threshold, there were two and five month-water year type combinations (3.3% and 8.3%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were five and four month-water year type combinations (8.3% and 6.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 55°F limit of successful smoltification, there were five and one month-water year type combinations (20.0% and 4.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were one and zero month-water year type combinations (4.0% and 0.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 1 would have positive water temperature-related effects on steelhead juvenile rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Table O-64. Summary of Results for Water Temperature Analyses for Steelhead Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66.2°F UPPER LIMIT OF OPTIMUM TEMPERATURES FOR JUVENILE STEELHEAD GROWTH, ASSUMING MAXIMUM RATION LEVELS							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above the Confluence with the San Joaquin River							
Favorable	3 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)
Unfavorable	2 (3.3%)	2 (3.3%)	2 (3.3%)	2 (3.3%)	2 (3.3%)	2 (3.3%)	2 (3.3%)
59.9°F JUVENILE PATHOGEN VIRULENCE THRESHOLD							
Orange Blossom Bridge							
Favorable	2 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)
Unfavorable	5 (8.3%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	3 (5.0%)	1 (1.7%)
Above the Confluence with the San Joaquin River							
Favorable	5 (8.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (6.7%)	0 (0.0%)
Unfavorable	4 (6.7%)	3 (5.0%)	3 (5.0%)	3 (5.0%)	3 (5.0%)	3 (5.0%)	3 (5.0%)
55°F LIMIT OF SUCCESSFUL SMOLTIFICATION							
Orange Blossom Bridge							
Favorable	5 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (12.0%)	0 (0.0%)
Unfavorable	1 (4.0%)	1 (4.0%)	1 (4.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)
Above the Confluence with the San Joaquin River							
Favorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (20.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are expected minor to moderate adverse and beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows are expected to have minor increases and decreases in fry and juvenile rearing habitat area across all water year types in the analyses in Attachment N.1, *Stanislaus River Habitat Availability Analysis* and moderate decreases in juvenile rearing habitat area depending on the month in the analyses in Attachment O.2, *CVPIA SIT LCM Habitat Estimates*. Water temperatures above the smoltification criteria are expected to have decreases in frequency in the Stanislaus River under Alternative 1.

Adult Upstream Migration and Holding

In the Stanislaus River, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as September and throughout March and can be recovered in the RST in Oakdale from November through April (Hellmair 2022; Eschenroeder et al. 2022).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Average flows in the Stanislaus River below Goodwin Dam are expected to generally increase November through April and decrease in October during adult migration and holding under Alternative 1 compared to the No Action Alternative (Table O-27 and Table O-28). The largest reduction in flow is a 77% decrease under Alternative 1 in October of a critically dry water year type (Table O-27). The largest increase in flow is a 74% increase under Alternative 1 in November of a below normal water year type. Average flows are lowest September through November under Alternative 1.

These results of the CalSim 3 simulated flows suggest that there may be a minor adverse and minor beneficial effect of Alternative 1 compared to the No Action Alternative on steelhead adult migration and holding in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range of minimal migration impairment for adult steelhead during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 4 for Orange Blossom Bridge and Table 6 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 8 for Orange Blossom Bridge and Table 10 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult upstream migration and holding pathogen virulence threshold during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 12 for Orange Blossom Bridge and Table 14 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-65. Table O-65, as described in Section O.4.10.6,reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 41°F to 66.2°F range of minimal migration impairment for adult steelhead under Alternative 1, there were 0 month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-65). There were zero and two month-water year type combinations (0.0% and 4.4%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence of the San Joaquin River, respectively. For the 69.8°F upper lethal limit to adult migrants there were zero and four month-water year type combination (0.0% and 8.9%, respectively) with favorable results at Orange Blossom Bridge and above the confluence of the San Joaquin River, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge, and above the confluence of the San Joaquin River. For the 59.9°F adult upstream migration and holding pathogen virulence threshold there was one month-water year type combination (2.2%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. There were four month-water year type combinations (8.9%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River.

These results suggest that Alternative 1 would have negligible water temperature-related effects on steelhead adult upstream migration and holding in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Table O-65. Summary of Results for Water Temperature Analyses for Adult Steelhead Upstream Migration and Holding for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
41°F–66.2°F RANGE OF MINIMAL MIGRATION IMPAIRMENT							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above Confluence							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (4.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
69.8°F UPPER LETHAL LIMIT TO ADULT MIGRANTS							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above Confluence							
Favorable	4 (8.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (4.4%)	0 (0.0%)
59.9°F ADULT UPSTREAM MIGRATION AND HOLDING PATHOGEN VIRULENCE THRESHOLD							
Orange Blossom Bridge							
Favorable	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	4 (8.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (6.7%)	0 (0.0%)
Above Confluence							
Favorable	1 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.2%)	0 (0.0%)
Unfavorable	4 (8.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (6.7%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are anticipated minor adverse and minor beneficial impacts of seasonal operations in the Stanislaus River on adult steelhead based on analyses of simulated flows and water temperature under Alternative 1 compared to the No Action Alternative. Under Alternative 1 compared to the No Action Alternative, there are potential adverse and beneficial impacts of changes in flow during critically dry water year types for adult migration and holding. Water temperatures outside the range or above the adult migration and holding criteria have negligible increases and decreases in frequency under Alternative 1 compared to the No Action Alternative.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Average flows in the Stanislaus River below Goodwin Dam are expected to be generally increased during kelt emigration under Alternative 1 compared to the No Action Alternative (Table O-27 and Table O-28). The largest reduction in flow is a 10% decrease under Alternative 1 in March of a above normal water year type below Goodwin Dam (Table O-27). The largest increase in flow is a 48% increase under Alternative 1 in March of a critically dry water year type at the mouth of the Stanislaus River (Table O-28). Flows are expected to be lowest in February and March of drier water year types under both the No Action Alternative under Alternative 1. The largest differences in these two months is a 40% increase in February of dry water year types under Alternative 1. Throughout the full simulation period under Alternative 1 compared to the No Action Alternative, average flows increase throughout the kelt emigration period at both locations (Table O-27 and Table O-28).

These results of the CalSim 3 simulated flows suggest that there are anticipated minor beneficial effects of Alternative 1 compared to the No Action Alternative on steelhead kelt emigration in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F limit of migration impairment for steelhead kelt emigration during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 20 for Orange Blossom Bridge and Table 22 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F lethal limit for steelhead kelt emigration during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 24 for Orange Blossom Bridge and Table 26 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F kelt emigration pathogen virulence threshold during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 28 for Orange Blossom Bridge and Table 30 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-66. Table O-66 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F limit of migration impairment for steelhead kelt emigration under Alternative 1, there were zero and three month-water year type combinations (0.0% and 12.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-66). There were zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 69.8°F lethal limit for steelhead kelt emigration there were zero and two month-water year type combinations (0.0% and 8.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were zero month-water year type combinations (0.0%) with unfavorable

results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 59.9°F kelt emigration pathogen virulence threshold there were one and five month-water combinations (4.0% and 20.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were one and zero month-water combinations (4.0% and 0.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin Rive, respectively. These results suggest that Alternative 1 would have positive water temperature-related effects to steelhead kelt emigration in the Stanislaus River.

Table O-66. Summary of Results for Water Temperature Analyses for Steelhead Kelt Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66.2°F LIMIT OF MIGRATION IMPAIRMENT							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above the Confluence with San Joaquin River							
Favorable	3 (12.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	2 (8.0%)	2 (8.0%)	2 (8.0%)	2 (8.0%)	1 (4.0%)	2 (8.0%)
69.8°F LETHAL LIMIT FOR KELT EMIGRATION							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above the Confluence with San Joaquin River							
Favorable	2 (8.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F PATHOGEN VIRULENCE THRESHOLD							
Orange Blossom Bridge							
Favorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Unfavorable	1 (4.0%)	1 (4.0%)	1 (4.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)
Above the Confluence with San Joaquin River							
Favorable	5 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (16.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	3 (12.0%)	3 (12.0%)	3 (12.0%)	3 (12.0%)	1 (4.0%)	3 (12.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are expected beneficial impacts of seasonal operations in the Stanislaus River on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 1 compared to the No Action Alternative. Under Alternative 1 compared to the No Action Alternative, there are potential minor beneficial impacts of flow for kelt emigration in critically dry water year types. Water temperatures above the three kelt emigration criteria are expected to have minor to moderate decreases in frequency in the Stanislaus River at the confluence with the San Joaquin River under Alternative 1 compared to the No Action Alternative.

O.4.11 Southern DPS Green Sturgeon

O.4.11.1 Sacramento River

Spawning and Egg Incubation

Green sturgeon adults spawn primarily from April through July, although they periodically spawn in late summer and fall (as late as October). Northern DPS green sturgeon eggs hatch about a week after fertilization (at 60ºF), and incubation time of Southern DPS green sturgeon eggs is assumed to be similar (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). Because the incubation time for green sturgeon is so short, the effects analysis period for incubating eggs is considered to be the same as the spawning period, April through July, occasionally extending to October.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

During the April through July green sturgeon spawning period, CalSim 3 estimates of mean monthly flows at RBDD (RM 244) under Alternative 1 range from about 5,547 cfs for April of critically dry water years to about 14,728 cfs for April of above normal water years (Table O-15). Mean flows during most of this period are moderate (~8,000 cfs to ~12,000 cfs). Differences in flows between Alternative 1 and the No Action Alternative are small in most months (up to 5%), but flows are moderately increased for Alternative 1 in June of wet, above normal, and below normal water years (up to 10%) and April and July of critically dry water years (up to 15%) (Table O-15). During the August through October period, when green sturgeon spawning occurs in occasional years, the flows under both alternatives tend to be lower than those in April through July, but the mean flows would be close to or above 5,000 cfs for all water year types in all three months. Moderate reductions in mean flows from the No Action Alternative to Alternative 1 are predicted for August and September of wet and above normal water years (up to 21%), August of below normal water years (10%), and October of above normal water years (6%); however, the resulting Alternative 1 mean flows range from about 6,000 to 9,000 cfs which are likely to be suitable for green sturgeon spawning and egg incubation (Table O-15). September and October spawning occurs only sporadically, so any effect on the green sturgeon population would be minor (National Marine Fisheries Service 2018b). Flow levels from April through July are likely

to be suitable for green sturgeon spawning and egg incubation, and no adverse effects are expected to result. Increases in mean flow from No Action Alternative to Alternative 1 in April, June, and July may or may not be substantial enough to have a positive effect on juvenile green sturgeon. The September and October flow reductions at RBDD are expected to have a minor adverse impact on green sturgeon.

CalSim 3 simulations at Hamilton City predict minor reductions in mean flow under Alternative 1 during July of above normal and below normal water years (up to 6%). Generally, mean flows during the April through July spawning and egg incubation period are lower at Hamilton City than at RBDD but remain similar to the No Action Alternative (~5,000 cfs to ~17,000 cfs) (Table O-17). Flows are predicted to moderately increase in April, May, and July of critically dry water years (up to 15%), and June of wet, above normal, and below normal water years (up to 16%). During the August through October spawning period, the flows under both alternatives tend to be lower than those in April through July. The mean flows for all water years in all three months are between ~4,000 cfs to ~7,800 cfs. Flow reductions are predicted under Alternative 1 for August and September of wet and above normal water years (up to 24%) and October of above normal water years (6%) (Table O-17). If flows are not suitable for green sturgeon spawning at Hamilton City, they would likely move upstream until they find suitable flows, therefore effects of reduced flows under Alternative 1 at Hamilton City are likely to be minor.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 49.3°F to 63.7°F range for spawning initiation during April through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 208 for Bend Bridge and Table 210 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 52.3°F to 60.8°F range supporting egg incubation during April through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 216 for Bend Bridge and Table 218 for Hamilton City.

Results for the two analyses are summarized in Table O-67. Table O-67, as described in Section O.4.8.1 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 49.3°F to 63.7°F spawning initiation range, there were zero and nine month-water year type combinations (0% and 45.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-67). There were no combinations (0%) with unfavorable results at both locations. For the 52.3°F to 60.8°F range for egg incubation, there were two and one combinations (10.0% and 5.0%, respectively) with favorable results Bend Bridge and Hamilton City, respectively. There were no combinations (0%) with unfavorable results at both locations. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 1 on green sturgeon spawning and egg incubation.

Table O-67. Summary of Results for Water Temperature Analyses for Green Sturgeon Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
49.3°F–63.7°F RANGE FOR SPAWNING INITIATION							
Below Bend Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	9 (45.0%)	4 (20.0%)	3 (15.0%)	5 (25.0%)	4 (20.0%)	5 (25.0%)	1 (5.0%)
Unfavorable	0 (0.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	2 (10.0%)
52.3°F–60.8°F RANGE FOR EGG INCUBATION							
Below Bend Bridge							
Favorable	2 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (10.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)
Hamilton City							
Favorable	1 (5.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)	5 (25.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts to potential adverse impacts on green sturgeon spawning and egg incubation habitat due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have beneficial impacts on spawning and egg incubation due to differences in water temperature.

Larval and Juvenile Rearing and Emigration

The green sturgeon spawning period is from April through July, so the larval period is considered to be April through September. The green sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch. The juveniles rear in the Sacramento River from about May through December. During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). Effects of flow and water temperature on green sturgeon larvae and juveniles may occur from April through December in the Sacramento River when analyzing the two life stages together.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling for the Sacramento River at RBDD indicates that mean monthly flows during the April through September period of larval rearing are generally similar between the No Action Alternative and Alternative 1 except, as described previously, for moderately higher mean flows in June of the wetter water year types and April and July of the drier water year types, and reduced flows during September of wet and above normal water years, August of wet, above normal, and below normal water years, and October of above normal water years under Alternative 1 (Table O-15). The September reductions in flow from the No Action Alternative to Alternative 1 would potentially affect green sturgeon larvae adversely because, as discussed in Section O.1.3.2.5, *Green Sturgeon, Southern DPS*, there appears to be a positive relationship between annual outflow and abundance of green sturgeon larvae and juveniles, but this conclusion is highly uncertain. Moderate increases in mean flow from No Action Alternative to Alternative 1 in April, June, and July may or may not be substantial enough to have a positive effect on larval green sturgeon.

CalSim 3 modeling for the Sacramento River at Hamilton City indicates that mean monthly flows during the period of juvenile rearing and emigration, May through December, are generally similar between the No Action Alternative and Alternative 1 except, as described previously, for reduced flows under Alternative 1 during August and September of wet and above normal water years; July, October and November of above normal water years; and July and August of below normal water years, resulting from fall X2 releases (Table O-17). These reductions in flow could negatively impact green sturgeon juveniles under Alternative 1 because, as discussed above, there appears to be a positive relationship between annual outflow and abundance of green sturgeon. Increases in mean flow from No Action Alternative to Alternative 1 in December, May and June may or may not be substantial enough to have a positive effect on juvenile green sturgeon (Table O-17).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 64.4°F upper threshold for larvae from May through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 220 for Bend Bridge and Table 222 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 66.2°F range of optimal juvenile bioenergetic performance during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 224 for Bend Bridge and Table 226 for Hamilton City.

Results for the two analyses are summarized in Table O-68. Table O-68as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 64.4°F upper water temperature limit for newly hatched larvae, there were zero and eight month-water year type combinations (0% and 40.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-68). There were zero and one combinations (0% and 5.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 59°F to 66.2°F range of optimal juvenile bioenergetic performance, there were zero and four combinations (0% and 26.7%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were three and zero combinations (20.0% and 0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 1 on green sturgeon larval and juvenile rearing and emigration.

Table O-68. Summary of Results for Water Temperature Analyses for Green Sturgeon Larval and Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
64.4°F UPPER LIMIT FOR NEWLY HATCHED LARVAE							
Below Bend Bridge							
Favorable	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	8 (40.0%)	5 (25.0%)	3 (15.0%)	6 (30.0%)	5 (25.0%)	7 (35.0%)	1 (5.0%)
Unfavorable	1 (5.0%)	1 (5.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	4 (20.0%)	0 (0.0%)
59°F–66.2°F RANGE OF OPTIMAL JUVENILE BIOENERGETIC PERFORMANCE							
Below Bend Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	1 (6.7%)
Unfavorable	3 (20.0%)	5 (33.3%)	6 (40.0%)	5 (33.3%)	5 (33.3%)	6 (40.0%)	1 (6.7%)
Hamilton City							
Favorable	4 (26.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	2 (13.3%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (13.3%)	2 (13.3%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts to minor adverse impacts on larval and juvenile rearing and emigration due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have beneficial and adverse impacts on larval and juvenile green sturgeon, depending on location, month, and water year type due to differences in water temperature.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Sacramento River from the Delta as early as February to make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence. After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). With the extended adult holding period, effects of flow and water temperature on adult upstream migration and holding may occur from February through December.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

Flows during the February through December period of green sturgeon immigration, spawning and holding would generally be similar between Alternative 1 and the No Action Alternative at RBDD, Hamilton City, and Wilkins Slough (Table O-15, Table O-17, and Table O-16). Exceptions include higher mean monthly flows under Alternative 1 at all locations during April, May, June, July, September, and December of various water year types and lower flows under Alternative 1 during August, September, and November (up to 24%). Increases in mean flow from No Action Alternative to Alternative 1 in April, May, June, July, September, and December may or may not be substantial enough to have a positive effect on larval green sturgeon. All of the more moderate flow differences occur within a range of river flows (~3,000 cfs to ~9,000 cfs) not expected to substantially affect upstream passage of migrating green sturgeon, but the August, September, and November flow reductions under Alternative 1 at Hamilton City and RBDD could result in reduced habitat quality in holding pool habitats, negatively impact holding adults.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52°F to 69.4°F range for adult migration during April through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 204 for Bend Bridge and Table 206 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 52°F to 73.4°F range for adult holding year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 212 for Bend Bridge and Table 214 for Hamilton City.

Results for the two analyses are summarized in Table O-69. Table O-69 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%. If the exceedance or occurrence value was >10% lower under the

alternative relative to the No Action Alternative, the result is termed “Favorable”. If the exceedance or occurrence value was >10% higher under the alternative relative to the No Action Alternative, the result is termed “Unfavorable”. The 10% value was chosen to represent a level of difference between the alternative and the No Action Alternative that could have a biologically meaningful effect on the species but considers the coarse definition in the data (e.g., a difference in just one of the 14 above normal water years represents a 7% difference). This value should not be interpreted as a significance threshold.

Under Alternative 1 for the 52°F to 69.4°F range for adult migration, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable or unfavorable results at both Bend Bridge and Hamilton City, respectively (Table O-69). For the 59°F to 73.4°F range for adult holding, there were zero and three combinations (0% and 5.0%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were 10 and three combinations (16.7% and 5.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 1 on green sturgeon adult upstream migration and holding.

Table O-69. Summary of Results for Water Temperature Analyses for Green Sturgeon Adult Upstream Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
52°F–69.4°F RANGE FOR ADULT MIGRATION							
Bend Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59°F–73.4°F RANGE FOR ADULT HOLDING							
Bend Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	1 (1.7%)	1 (1.7%)
Unfavorable	10 (16.7%)	12 (20.0%)	13 (21.7%)	12 (20.0%)	12 (20.0%)	15 (25.0%)	6 (10.0%)
Hamilton City							
Favorable	3 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	1 (1.7%)
Unfavorable	3 (5.0%)	2 (3.3%)	2 (3.3%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have potential adverse impacts on upstream migration and holding habitats due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have beneficial and adverse impacts on upstream migration and holding depending on location, month, and water year type due to differences in water temperature.

O.4.11.2 San Joaquin River

Green sturgeon are also present in the San Joaquin River, but at considerably lower numbers than white sturgeon. Anglers have reported catching green sturgeon in the San Joaquin River and one adult green sturgeon was captured by Reclamation in April of 2020 (Root et al., 2020). Although the reported presence of green sturgeon in the San Joaquin River coincides with the spawning migration period of green sturgeon within the Sacramento River, no evidence of spawning has been detected (Section O.1.8.2.3, *Green Sturgeon, Southern DPS*).

Potential Changes to Green Sturgeon from Seasonal Operations

CalSim 3 Flows

Since green sturgeon spawning has not been confirmed in the San Joaquin River, life stage analyses were not performed. It is assumed that adult green sturgeon could be in the San Joaquin River during all months of the year.

During the evaluated months, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 1 range from about 704 cfs for July of critically dry water years to about 12,545 cfs for April of wet water years (Table O-29). CalSim 3 results predict increased flows under Alternative 1 compared to the No Action Alternative during February through September of various water year types. Substantially increased flows are predicted for July of dry and critically dry water years (up to 26%) and August and September of critically dry water years (up to 23%). Flows under Alternative 1 would decrease in October of all except wet water year types (up to 10%) and in November of critically dry water years (6%) (Table O-29). Because green sturgeon are uncommon in the San Joaquin River and can easily relocate to other parts of the Bay Delta system that have adequate flow, it is not anticipated that flow reductions under Alternative 1 would have an effect on green sturgeon compared to the No Action Alternative. Increased flows predicted for the majority of the months may have a beneficial effect on adult green sturgeon.

Summary

Alternative 1 relative to the No Action Alternative is expected to have possible beneficial impacts on adult green sturgeon due to differences in flow. Due to the lack of information about green sturgeon life stages in the San Joaquin River, a temperature analysis was not done for this species in this geography.

O.4.11.3 Bay-Delta

Larval and Juvenile Rearing and Emigration

After hatching, green sturgeon larvae and juveniles migrate downstream toward the Delta. Juveniles are believed to use the Delta for rearing for the first one to three years of their lives before moving out to the ocean and are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, especially within the central Delta and Suisun Bay/Marsh (Section O.1.9.1.5, *Green Sturgeon, Southern DPS*).

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

Differences in hydrology in the Delta under Alternative 1 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using two models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions. In addition to these two analyses, a Delta Outflow vs. Sturgeon YCI regression analysis was done for the two sturgeon species to evaluate flow effects on sturgeon year class index.

Zone of Influence

For a detailed description of how flows under Alternative 1 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2, *Zone of Influence*).

Flow into Junctions

For a detailed description of how flows under Alternative 1 may impact the flow at Head of Old River and CVP, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2, *Flow into Junctions*).

Delta Outflow vs Sturgeon YCI

There are currently no tools available to directly evaluate the effect of spring outflow on green sturgeon. Thus white sturgeon are used as a proxy species for green sturgeon. To evaluate the effect of spring outflow on green sturgeon, a Delta Outflow vs. Year-Class Strength[1] regression analysis was done. This analysis is a response to the NMFS Green Sturgeon Recovery Plan that suggested larval abundance and distribution may be influenced by spring and summer outflow. The recovery plan also suggested that recruitment may be highest in wet years, making water flow an influential habitat parameter (National Marine Fisheries Service 2018a:12). As noted by NMFS (2018b:12), there are correlations between white sturgeon and Delta outflow, which have previously been used to infer potential effects on green sturgeon (ICF International 2016).

[1] Year-class strength in this case is an index of year-class abundance based on age-0 and age-1 white sturgeon abundance indices from otter trawling by the San Francisco Bay Study (Fish 2010).

In contrast to white sturgeon, there are currently no quantitative relationships established between green sturgeon and Delta flows. There appears to be a positive relationship between annual outflow and abundance of green sturgeon larvae and juveniles in RSTs at Red Bluff Diversion Dam (Heublein et al. 2017a). More recently, CDFW found that catch per unit effort of yearling juvenile green sturgeon sampled in the Delta was about 10 times as high in years following wet water years as in years following dry and critically dry water years (Beccio 2021). These factors are generally suggestive of a positive relationship with flow, but it is uncertain the extent to which such effects may reflect water operations.

The Delta Outflow Year-Class Strength regression analysis found statistically significant positive correlations between white sturgeon year-class strength and Delta outflow for April-May and March-July. The analysis is used as a surrogate for green sturgeon. For the April-May Delta outflow, the average overall YCI values would be generally similar between Alternative 1 (10.7) and the No Action Alternative (11.2) (Table O-70). The same is true for the March-July Delta outflow, with the average overall YCI value for Alternative 1 being 16.4 compared to 16.7 for the No Action Alternative (Table O-71). Any effects of Alternative 1 on green sturgeon relative to the No Action Alternative are expected to be limited given the limited differences in average Delta flow conditions between the two alternatives over all water year types during the specified months. For more detailed information see summaries presented in Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*.

Table O-70. Year-Class Strength of White Sturgeon (Percent Difference from No Action Alternative), Based on April–May Regression With Delta Outflow

Water Year Type	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
Wet	30.3	29.1 (-4%)	29 (-4.3%)	29 (-4.3%)	29.5 (-2.6%)	29.7 (-2%)	50.2 (65.5%)	29.1 (-4%)
Above Normal	5.8	5.1 (-12.1%)	5.2 (-10.3%)	5.1 (-12.1%)	5.4 (-6.9%)	6 (3.4%)	9.2 (58.6%)	5.2 (-10.3%)
Below Normal	3.5	3.2 (-8.6%)	3.2 (-8.6%)	3.2 (-8.6%)	3.4 (-2.9%)	3.8 (8.6%)	4.6 (30.9%)	3.2 (-8.6%)
Dry	2.2	2.2 (0%)	2.2 (0%)	2.2 (0%)	2.2 (0%)	2.4 (9.1%)	2.6 (17.3%)	2.2 (0%)
Critically Dry	1.4	1.6 (14.3%)	1.5 (7.1%)	1.6 (14.3%)	1.6 (14.3%)	1.7 (21.4%)	1.7 (21.4%)	1.5 (7.1%)
All	11.2	10.7 (-4.5%)	10.7 (-4.5%)	10.7 (-4.5%)	10.9 (-2.7%)	11.2 (0%)	18 (59.9%)	10.7 (-4.5%)

Table only includes annual mean responses and does not consider model uncertainty. White sturgeon is used as a proxy species for green sturgeon.

Table O-71. Year-Class Strength of White Sturgeon (Percent Difference from No Action Alternative), Based on March–July Regression With Delta Outflow

Water Year Type	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
Wet	48.9	48.5 (-0.8%)	47.9 (-2%)	47.9 (-2%)	48.3 (-1.2%)	48.3 (-1.2%)	66.4 (35.9%)	47.9 (-2%)
Above Normal	6.7	5.9 (-11.9%)	6.3 (-6%)	6.2 (-7.5%)	6.6 (-1.5%)	6.8 (1.5%)	8.3 (24.2%)	6.4 (-4.5%)
Below Normal	2.9	2.6 (-10.3%)	2.8 (-3.4%)	2.8 (-3.4%)	2.9 (0%)	3.1 (6.9%)	3.5 (19.7%)	2.8 (-3.4%)
Dry	2.0	1.9 (-5%)	1.9 (-5%)	1.9 (-5%)	2 (0%)	2.1 (5%)	2.3 (18.7%)	1.9 (-5%)
Critically Dry	1.2	1.3 (8.3%)	1.2 (0%)	1.3 (8.3%)	1.3 (8.3%)	1.4 (16.7%)	1.4 (20.5%)	1.2 (0%)
All	16.7	16.4 (-1.8%)	16.3 (-2.4%)	16.3 (-2.4%)	16.6 (-0.6%)	16.6 (-0.6%)	22.4 (34.2%)	16.4 (-1.8%)

Table only includes annual mean responses and does not consider model uncertainty. White sturgeon is used as a proxy species for green sturgeon.

Summary

Alternative 1 relative to the No Action Alternative is expected to influence flow into the Head of Old River and CVP junctions. Under Alternative 1, possibly less flow into CVP under OMR -2,000 and -5,000; possibly less flow into HOR under all OMR groups. Impacts of pumping under both Alternative 1 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI). Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on green sturgeon year class strength due to differences in flow, using white sturgeon as a proxy for green sturgeon.

Potential Changes to Entrainment of Southern DPS Green Sturgeon

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on green sturgeon entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for green sturgeon include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of green sturgeon at SWP Banks Pumping Plant for January and March of all water year types, was greater under Alternative 1 than predicted average monthly loss under the No Action Alternative; up to 149% greater for below normal water year types (Table O-72). Predicted average monthly loss of green sturgeon at CVP Jones Pumping Plant for June and July under Alternative 1 was greater than predicted average monthly loss under the No Action Alternative; up to 17% greater, in all water year types except for dry water years, where loss under Alternative 1 was 1% less than the No Action Alternative (Table O-73). It should be noted that loss of green sturgeon at both facilities is rare with such low values of predicted loss that the percent differences may not be representative. For more detailed information on average monthly loss by water year type (Attachment I.2, *Salvage Density Model Loss Simulation*).

Table O-72. Predicted Average Monthly Loss of GST at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	1	1 (29%)	1 (6%)	1 (7%)	1 (4%)	1 (3%)	0 (-58%)	1 (12%)	1: March
Above Normal	1	1 (89%)	1 (-4%)	1 (-4%)	0 (-18%)	0 (-18%)	0 (-18%)	1 (-1%)	1: March
Below Normal	1	4 (149%)	1 (-3%)	1 (-3%)	1 (-3%)	1 (-3%)	1 (1%)	1 (-3%)	1: Jan.
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Table O-73. Predicted Average Monthly Loss of GST at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	7	7 (0%)	6 (-6%)	6 (-6%)	6 (-6%)	6 (-6%)	4 (-46%)	6 (-6%)	1: June
Above Normal	6	7 (17%)	5 (-9%)	5 (-9%)	5 (-8%)	5 (-8%)	1 (-79%)	5 (-9%)	1: June
Below Normal	0	0	0	0	0	0	0	0	No Fish
Dry	1	1 (-1%)	1 (-14%)	1 (-13%)	1 (-12%)	1 (-10%)	0 (-89%)	1 (-11%)	2: June–July
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on the entrainment of juvenile green sturgeon at both facilities due to differences in flow. Results from the quantitative model show possible adverse impacts, but since green sturgeon are salvaged so rarely, the numbers may not be representative.

Adult Upstream Migration and Holding

Adult green sturgeon move through the Delta from February through April to get to spawning locations in the upper Sacramento River. Following their initial spawning run upriver, adults split into two out migration groups, the "early" out migration group may migrate immediately back downstream through the Delta during May and June, or the "late" out migration group may hold for a few weeks to months in the upper river before moving back downstream during November through January (Section O.1.9.1.5, *Green Sturgeon, Southern DPS*).

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

Delta Outflow vs. Sturgeon YCI

The Delta outflow vs Sturgeon YCI regression analysis results apply to all life stages of green sturgeon found in the Bay Delta. The regression analysis, used as a surrogate for green sturgeon, found statistically significant positive correlations between white sturgeon year-class strength and Delta outflow for April-May and March-July. Under Alternative 1, April-May Delta outflow average overall YCI values would be 4.5% lower (Table O-70) and the March-July Delta outflow values would be 1.8% lower (Table O-71) compared to the No Action Alternative. Refer to the analysis in Section O.4.11.3.1, *Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on green sturgeon year class strength due to differences in flow.

O.4.12 Delta Smelt

O.4.12.1 Bay-Delta

Adult Migration and Spawning

During winter, adult Delta smelt initiate upstream spawning migration in association with "first flush" flow events (Sommer et al. 2011). Others report this seasonal change as a multi-directional and more circumscribed dispersal movement to freshwater areas throughout the Delta region (Murphy and Hamilton 2013). By late winter-spring, after arriving in freshwater staging habitats, adult Delta smelt hold until spawning commences during favorable water temperatures (Bennett 2005; Grimaldo et al. 2009; Sommer et al. 2011; Damon et al. 2016). Delta smelt spawn over a wide area throughout much of the Delta, including the Sacramento River and San Joaquin River confluence, the upper Sacramento River, and Cache Slough as well as into Suisun Marsh and the Napa River as conditions allow (Brown et al. 2014; Murphy and Hamilton 2013). Spawning of Delta smelt has not been observed in the wild (Moyle et al. 2016).

Potential Changes to Delta Smelt from Seasonal Operations

Alternative 1 compared with the No Action Alternative may have effects on migrating and spawning adult Delta smelt due to differences in flows including the location and size of the LSZ (as indexed by X2 position), population growth rate, and prey availability. These possible differences were evaluated using several quantitative models.

CalSim 3 X2 Modeled X2 Position

While Delta smelt can occupy a wide range of habitats and salinities, historically a majority of Delta smelt reside in or near the low salinity zone (LSZ, 0.5–6 psu) (Merz et al. 2011, Moyle et al. 1992). X2 (the location of the 2 psu salinity isohaline measured as its distance in kilometers from the Golden Gate Bridge is located) has been used as a proxy for the LSZ (MacWilliams et al. 2015, Kimmerer et al. 2013, Jassby et al. 1995). The position of X2 responds to CVP and SWP operations as well as precipitation, because more freshwater outflow through the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and at the confluence of the Sacramento and San Joaquin Rivers (X2 ~ 80-85 km).

The position of X2 under Alternative 1 was similar to the No Action Alternative (Table O-18) during the adult Delta smelt migration and spawning period, only varying one to three km from the No Action Alternative, likely having negligible effects on adult Delta smelt in the winter and spring.

USFWS Life Cycle Model

The geometric mean of the expected rate of change in abundance across years (1995-2015), lambda (λ), for Alternative 1 was 0.69 (Attachment F.4, *Delta Smelt Life Cycle Model with Entrainment*). The geometric means of the expected population growth rate varied across water year types, from λ equal to 0.52 (-48% decline on average) for below normal, dry and critically dry water years, to 0.96 (-4% decline on average) for wet and above normal years. Unlike the other Alternatives, Alternative 1 did not result in positive expected growth in abundance during wet and above normal water year types, and predicted growth rates were generally lower for this Alternative than those for the other alternatives considered. Compared to the No Action Alternative, Alternative 1 resulted in rates of population growth that were between 25% to 26% lower on average, depending on the water year type, with the most pronounced difference during wet and above normal years. During wet and above normal years, Alternative 1 resulted in a slight population decline (-4% per year on average) compared to a 28% rate of positive growth on average during wet and above normal years under the No Action Alternative.

Revised Maunder and Deriso Life Cycle Model

The population growth rate, λ, integrates all life stages, but is calculated based on abundance of adults. For the Maunder and Deriso in R (MDR) model, relative to the No Action Alternative, model projections under Alternative 1 indicated a substantial adverse impact, with Delta smelt population growth rate lower than for the No Action Alternative in all modeled years (1995-2015; Attachment F.1, *Maunder and Deriso in R Model*). The geometric mean of λ was 0.58

across all water year types, 23% lower than for the No Action Alternative ($\lambda = 0.75$), and the magnitude of this difference remained similar for both drier and wetter water years.

Because the MDR is an integrated life cycle model, the effects of each Alternative were evaluated quantitatively primarily based on year-to-year changes in the population growth rate metric. However, as a statistical model fitted to abundance data for multiple life stages, it is possible to gain a qualitative understanding of the season-specific covariates with a statistically significant influence on each life stage. Also, because the covariates are standardized prior to model fitting, their coefficients can be directly compared.

In the MDR model, survival from the sub-adult to adult stage can be influenced by winter covariates which are averaged across the December to February period. Model selection retained combined Old and Middle River flow (OMR) and mean Secchi depth at South Delta monitoring stations as significant covariates of sub-adult survival, with coefficients of 0.477 and 0.542, respectively. Although differences in hydrology between the Alternatives would be expected to influence turbidity, the relationship is complex and was not able to be addressed for this analysis. Within the MDR, impacts on sub-adult survival are therefore related only to differences in OMR between the Alternatives. Alternative 1 results in substantially more negative OMR flows during the winter period; on average 70% more negative than under the No Action Alternative (Attachment F.1, *Maunder and Deriso in R Model*). This indicates a high potential for an adverse effect on sub-adult to adult Delta smelt survival under Alternative 1.

Zooplankton CPUE-Outflow Analysis

Analysis of catch per unit effort (CPUE) with outflow during the winter in the low salinity zone showed significant relationships for 5 zooplankton taxa; *Daphnia* adults, decapod larvae, *Eurytemora affinis* adults, other calanoid adults, and other calanoid copepodites. Under Alternative 1, when compared to the No Action Alternative, *Daphnia* adult CPUE was not expected to change in the wet, below normal, and critically dry water year types. *Daphnia* adult CPUE had the largest expected decrease of 14% during the dry water year type. Results for decapod larvae were negligible when rounded to the nearest whole integer (values were 0) across all WYT and scenarios. *Eurytemora affinis* (adults) CPUE, had the smallest expected decrease of 1% during the wet water year type, and the largest decrease of 12% during the critically dry water year type. For other calanoid copepod adult CPUEs (*Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), the smallest expected decrease of 3% was during the wet water year type and the largest expected decrease of 33% was during dry water year type. For other calanoid copepod copepodites (*Acartia* spp., *Acartiella* spp., unidentified calanoids, *Eurytemora affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), CPUE was expected to decrease 2% during the wet water year types and 16% during the critically dry water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most winter months and water year types (Table O-20) resulting in lower zooplankton CPUE.

Analysis of CPUE with outflow during the spring showed significant relationships for the five zooplankton taxa. Under Alternative 1, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 13% during the critically dry water year type and the largest expected CPUE decrease of 8% during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 6% during the critically dry

water year type and the largest expected CPUE decrease of 5% during the above normal and below normal water year type. Harpacticoids had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the below normal water year type. Other calanoid adults had the largest expected CPUE increase of 8% during the critically dry water year type and the largest expected CPUE decrease of 6% during the above normal and below normal water year type. Other calanoid copepodites had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 4% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most spring months and water year types, except in April during the critically dry water year type (Table O-20) resulting in lower zooplankton CPUE in all other water year types but an increase in the CPUE during the critically dry water year type compared to the No Action Alternative.

Summary

Alternative 1 relative to the No Action Alternative is expected to have an adverse impact on adult Delta smelt migration and spawning due to differences in flow. Compared to the No Action Alternative, CPUE of Delta smelt prey species is expected to be lower under Alternative 1. Results from the Maunder and Deriso life cycle model indicate that under Alternative 1 there would be a substantially lower population growth rate and suggests lower sub-adult to adult survival during the winter. These results generally agreed with the results from the USFWS life cycle model which found lower population growth rates under Alternative 1 when compared to the No Action Alternative, particularly during the below normal, dry, and critically dry water year types. CalSim3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the winter and spring which is expected to have no impact on adult Delta smelt migration and spawning.

Potential Changes to Entrainment of Delta Smelt

Alternative 1 relative to the No Action Alternative may affect the entrainment of adult Delta smelt due to differences in flows. Entrainment varies annually and depends on a combination of hydrology, turbidity, and export rates (see Smith et al. 2021). Historic salvage shows adult Delta smelt are entrained in the Delta Fish Collection Facilities, however in more recent years fewer fish have been entrained likely due to a combination of changes to operations and the continued decline of the Delta smelt population. While the USFWS life cycle model does incorporate entrainment, it was not used to evaluate entrainment of adult Delta smelt. Instead, OMR flows were used to evaluate changes between Alternative 1 and the No Action Alternative.

CalSim3 OMR Values

OMR combined flows was more negative under Alternative 1 when compared to the No Action Alternative from January to June which would have adverse effects on entrainment of adult Delta smelt (Table O-21). The largest difference in OMR flows were in January during the above normal water year type (105% more negative) while the smallest difference was in March during the critically dry water year type (3% more positive). In general, during the January to June period, OMR was more negative under Alternative 1 compared to the No Action Alternative which would have an adverse effect on adult Delta smelt entrainment.

Summary

Alternative 1 relative to the No Action Alternative is expected to have an adverse impact on the entrainment of adult Delta smelt due to differences in flow. Alternative 1 relative to the No Action Alternative is in general more negative from January to June which can lead to increased entrainment of adult Delta smelt due to differences in OMR flow.

Eggs and Larvae

Eggs hatch after an average of 10 days in the spring and planktonic larvae are transported (advected) from freshwater regions by the Sacramento River and tidal flows from March through May. The larval stage lasts for an average of 30 days. The nonpelagic habitats used by larval Delta smelt before they move into the pelagic areas are not known (Swanson et al. 1998; Sommer et al. 2011).

Potential Changes to Delta Smelt from Seasonal Operations

Alternative 1 compared with the No Action Alternative may have effects on Delta smelt larvae including X2 position and prey availability due to differences in flows. These possible differences were evaluated using a quantitative model.

CalSim3 X2 Modeled X2 Position

While Delta smelt can occupy a wide range of habitats and salinities, historically a majority of Delta smelt reside in or near the LSZ (Merz et al. 2011, Moyle et al. 1992). X2 has been used as a proxy for the LSZ (MacWilliams et al. 2015, Kimmerer et al. 2013, Jassby et al. 1995). The position of X2 responds to CVP and SWP operations, the more freshwater outflow into the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and at the confluence of the Sacramento and San Joaquin Rivers (X2 ~ 80-85 km).

The position of X2 under Alternative 1 was similar to the No Action Alternative (Table O-18) during the larval Delta smelt period, only varying one to three-km from the No Action Alternative, likely having negligible effects on larval Delta smelt in the spring.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the spring showed significant relationships for five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. Under Alternative 1, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 13% during the critically dry water year type and the largest expected CPUE decrease of 8% during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the above normal and below normal water year type. Harpacticoids had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the below normal water year type. Other calanoid adults had the largest expected CPUE increase of 8% during the critically dry water year type and the largest

expected CPUE decrease of 6% during the above normal and below normal water year type. Other calanoid copepodites had the largest expected increase of 6% during the critically dry water year type (6%) and the largest expected CPUE decrease of 4% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most spring months and water year types, except in April during the critically dry water year type (Table O-20) resulting in lower zooplankton CPUE in all other water year types but an increase in CPUE during the critically dry water year type compared to the No Action Alternative.

Revised Maunder and Deriso Life Cycle Model

Life cycle analysis with the Maunder and Deriso Model in R (MDR) did not identify any significant covariates of recruitment, and so did not evaluate effects on eggs or early larval stages.

Summary

Alternative 1 relative to the No Action Alternative would have an adverse impact on Delta smelt larvae due to differences in flow. Compared to the No Action Alternative, CPUE of Delta smelt prey species is expected to be lower under Alternative 1. Results from the revised Maunder and Deriso life cycle model did not identify any significant covariates of recruitment, and so did not evaluate impacts on eggs or early larval stages. CalSim3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the spring which is expected to have negligible impacts on larval Delta smelt.

Potential Changes to Entrainment of Delta Smelt

Differences in flows under Alternative 1 compared with the No Action Alternative may have effects on entrainment of Delta smelt larvae. These possible differences were evaluated using a quantitative model.

Particle Tracking Model (PTM)

Differences in flow between Alternative 1 compared with the No Action Alternative could have an effect on the entrainment of larval Delta smelt. This possible difference was evaluated using PTM.

The CalSim 3 model simulated operational conditions under a range of OMR and inflow conditions from the Sacramento and San Joaquin rivers, with the DSM2 PTM module allowing for an assessment of entrainment of neutrally buoyant passive particles (a proxy for larval Delta smelt, generally distributed throughout the water column) at export facilities (Attachment I.8, *Particle Tracking Fate Modeling of Larval Smelt Entrainment*). PTM analysis was only considered for the larval Delta smelt life stage since modeling suggests later Delta smelt life stages are likely not neutrally buoyant and have a behavioral response to maintain horizontal position in the estuary (Gross et al. 2021, Kimmerer and Nobriga 2008). Results discussed here are expressed as percent of particles with a fate of *Entrained at Exports*. Please refer to Attachment I.3, *Delta Export Zone of Influence Analysis*, for keys to inflow and OMR bins codes, including corresponding Sacramento and San Joaquin rivers flow ranges and mean OMR and Exports flow ranges. The following narrative focuses on three injection regions when

assessing potential entrainment effects from the perspective of varying inflows (Inflow bins: *Sacramento River, San Joaquin River*, and *Yolo Bypass Region*) and one injection region when assessing potential effects from the perspective of OMR net flows (OMR bins: *San Joaquin River Region*).

Inflow Bins.

Depending on inflow conditions, an average of 1 to 14% of particles injected within the Sacramento River region would be entrained at export facilities under Alternative 1, compared to 0 to 14% under the No Action Alternative. The average percentage of particles entrained at exports ranged from 4% lower (for low Sacramento River and medium San Joaquin River flows, "lomed", 5% *vs* 6%) to 406% higher under Alternative 1 than under the No Action Alternative ("himed", 8% *vs* 2%).

Depending on inflow conditions, an average of 55 to 95% of particles injected within the San Joaquin River region would be entrained at export facilities under Alternative 1, compared to 45 to 87% under the No Action Alternative. Differences in potential entrainment between Alternative 1 and the No Action Alternative were minimal for "medlo" (+1%) and "lolo" (+2%) inflows and maximal under "medhi" inflow conditions (+40%). Although not discussed here in detail, a similar pattern was observed for other injection regions with moderate potential for particle entrainment. Alternative 1 would generally lead to small reductions to small increases in the average percentage of particles entrained compared to the No Action Alternative under low to medium Sacramento river inflows and low San Joaquin river flows (from -4% for the Central Delta injection region or -3% for the Mokelumne River injection region under "lolo" conditions to +6% or +4%, respectively, under "medlo" conditions) and to the largest increases in potential entrainment under medium to high inflow conditions compared to the No Action Alternative (up to +177% for the Central Delta injection region or +145% for the Mokelumne River injection region under "himed" conditions).

Depending on inflow conditions, an average of 0 to 5% of particles injected within the Yolo Bypass region would be entrained at export facilities under both Alternative 1 and the No Action Alternative. The average percentage of particles entrained at exports was slightly lower under Alternative 1 than under the No Action Alternative under low Sacramento River flows (from -8% to -6% for "lolo" and "lomed" inflow bins, respectively) and greater than under the No Action Alternative at higher inflows (up to +784% under "himed" conditions, although the total entrainment for this injection site remained low at 2% *vs* 0%).

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), there was a difference between the average percentage of particles entrained under Alternative 1 and under the No Action Alternative (-1 to +30%).

OMR bins.

Depending on OMR flow conditions, an average of 56 to 77% of particles injected within the San Joaquin River region would be entrained at export facilities under Alternative 1, compared to 57 to 87% under the No Action Alternative. Potential entrainment ranged from 11% lower under Alternative 1 than under the No Action alternative for the -5000 OMR bin (77 *vs* 87%) to 7% higher under Alternative 1 for the -3500 bin (72 *vs* 68%). Although not discussed here in detail, a similar pattern was observed for other injection regions with moderate potential for particles entrainment at export facilities (Mokelumne River, Sacramento River, Central Delta): Alternative 1 would generally lead to substantial reductions in the average percentage of particles entrained compared to the No Action Alternative for the most negative OMR index (-5000), to increases for intermediate OMR index (-3500) and either little or variable change under the less negative OMR index (-2000).

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of OMR flow conditions, there was generally little to no difference between the average percentage of particles entrained under Alternative 1 and under the No Action Alternative (-3 to +0%).

Summary

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), Alternative 1 relative to the No Action Alternative is expected to have a negligible to adverse impact on the entrainment of larval Delta Smelt due to differences in flow, depending on particle origin and inflow grouping. For injection regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta) Alternative 1 relative to the No Action Alternative is expected to have a negligible to minor beneficial impact on the entrainment of larval Delta Smelt, depending on OMR grouping.

Juveniles

During and after larval rearing in freshwater, many young Delta smelt move with river and tidal currents during the early summer to remain in favorable rearing habitats, often moving into low salinity (< 6 psu) areas to avoid seasonally warm and highly transparent waters that typify many areas in the central Delta (Nobriga et al. 2008). Juvenile Delta smelt rearing habitat is correlated with salinity, particularly the position of the LSZ, and other habitat attributes including turbidity and temperature. Delta smelt also rear in upstream areas such as the Cache Slough complex and Sacramento Deep Water Ship Channel, depending on habitat conditions (Sommer and Mejia 2013). Studies indicate that in fall, prior to spawning, juvenile and sub-adult Delta smelt tend to remain in the LSZ (Sommer et al. 2011), though they can be found in the lower San Joaquin River, Suisun and San Pablo bays, the Sacramento River and San Joaquin River confluence, Cache Slough, and the lower Sacramento River (Murphy and Hamilton 2013).

Potential Changes to Delta Smelt from Seasonal Operations

Alternative 1 compared with the No Action Alternative may have effects on juvenile Delta smelt including the location and size of the LSZ (as indexed by X2 position), estimated summer and fall habitat, population growth rate, and prey availability due to differences in flow. These possible differences were evaluated using several quantitative models.

CalSim3 X2 Modeled X2 Position

While Delta smelt can occupy a wide range of habitats and salinities, historically a majority of Delta smelt reside in or near the LSZ (Merz et al. 2011, Moyle et al. 1992). X2 has been used as a proxy for the LSZ (MacWilliams et al. 2015, Kimmerer et al. 2013, Jassby et al. 1995). The position of X2 responds to CVP and SWP operations, the more freshwater outflow into the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and at the confluence of the Sacramento and San Joaquin rivers (X2 ~ 80-85 km).

The position of X2 under Alternative 1 was similar to the No Action Alternative (Table O-18) during the juvenile Delta smelt period, only varying 1-3 km from the No Action Alternative, likely having negligible effects on juvenile Delta smelt in the summer. However, during the fall period, CalSim3 modeling indicates that the estimated X2 position under Alternative 1 when compared to the No Action Alternative increases in the early fall (September–October) during the wet and above normal water year types (7-8 km further landward) which may have an adverse effect on juvenile Delta smelt by reducing the size of the LSZ

Habitat Suitability Index

Juvenile Delta smelt summer and fall habitat was estimated for different water year types (wet, above normal, below normal, dry, and critical) using the Bever et al. (2016) habitat suitability index (Bever HSI) and the Bever HSI with a water temperature threshold of 22° Celsius (22C HSI), where the Bever HSI value is multiplied by 0 when water temperature is greater than 22° C and by 1 when water temperature is less than or equal to 22° C. The temperature threshold of 22ºC was used based on sub-lethal physiological and behavioral effects observed in multiple studies (Davis et al. 2022, Hammock et al. 2022, Komoroske et al. 2021, Lewis et al. 2021, Davis et al. 2019, Komoroske et al. 2015). Under Alternative 1, mean Bever HSI for subregions targeted by the summer fall habitat action (Yolo Bypass, which includes Cache Slough and Sacramento Deepwater Shipping Channel; Lower Sacramento River; Confluence; Suisun Marsh; northwest Suisun Bay) was 16% lower to 1% higher than under the No Action Alternative, depending on water year type. Under Alternative 1, the mean 22C HSI for the summer fall habitat action subregions was 8% to 28% lower than under the No Action Alternative, depending on water year type. The largest differences under Alternative 1 are predicted during the above normal water year for Bever HSI (16% lower) and during the wet water year for 22C HSI (28% lower). The smallest differences are predicted during the critical water year for Bever HSI (1% higher) and during the below normal water year for 22C HSI (8% lower).

The results of the HSI analyses suggest that Alternative 1 may result in minor increases (1%) to decreases (8%–28%) in suitable habitat depending on water year type and the application of a temperature threshold in comparison to the No Action Alternative and would likely have negligible to adverse impacts on juvenile Delta smelt summer and fall habitat.

Revised Maunder and Deriso Life Cycle Model

Survival between the post-larval and juvenile stages is influenced by summer variables, and model selection identified two significant covariates: cumulative June-August outflow and June-August mean water temperature with coefficients of 0.354 and -0.351, respectively (Attachment F.1, *Maunder and Deriso in R Model*). Although differences in hydrology between the alternatives would be expected to influence temperature, the relationship is complex and was not able to be addressed for this analysis. Within the MDR, impacts on post-larval survival are therefore related only to differences in summer outflow between the alternatives. Summer outflow did not vary substantially between alternatives, but Alternative 1 did result in the lowest mean summer outflow (approximately 3% lower than the No Action Alternative), indicating the potential for a minor adverse impact on post-larval survival.

The preferred set of covariates identified through extensive model selection did not include any parameters that differed between alternatives (Attachment F.1, *Maunder and Deriso in R Model*). Mean Delta water temperature and Secchi depth were the selected parameters for the fall period, which correspond to juvenile survival in the MDR model. Although hydrological differences between the alternatives would potentially impact these variables, the relationships between flow, temperature and turbidity are complex, and were not able to be modeled for this exercise. As such, juvenile Delta smelt survival under Alternative 1 was the same as under the No Action Alternative.

Zooplankton CPUE-Outflow Analysis

During the summer months (May to August), the zooplankton-outflow analysis showed no significant relationships between outflow and zooplankton CPUE. Several studies have previously found relationships between abundance of zooplankton taxa and outflow during the summer (e.g. Kimmerer 2002, Kimmerer et al. 2018) while other studies have found mixed effects (Frantzich et al. 2021) or no effects (Sommer et al. 2020) of increased flow on zooplankton abundance. Evaluating possible benefits of increased outflow and flow pulses during summer may be difficult given sampling frequency and the effect size of increases to zooplankton abundances (Brandon et al. 2021).

Analysis of CPUE with outflow during the fall showed significant relationships for two taxa; *E. affinis* adults and mysids. Under Alternative 1, when compared to the No Action Alternative, for *E. affinis* there was no expected change in CPUE in the below normal and critically dry water year types and the largest decrease of 67% during the above normal water year type. However, the expected CPUE for *E. affinis* during the fall was very low (1–3 individuals per cubic meter) and unlikely to impact Delta smelt juveniles. For mysids, there was no expected change in CPUE in the dry and critically dry water year types and the largest decrease of 42% was during the above normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most fall months and water year types, (Table O-20) resulting in lower zooplankton CPUE.

Summary

Alternative 1 relative to the No Action Alternative is expected to have no impact to adverse impacts on juvenile Delta smelt due to differences in flow. CalSim3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the summer which is expected to have no impact on juvenile Delta smelt, however there is likely an adverse impact during wet and above normal years on juvenile Delta smelt during the fall since the position of X2 will be further landward. The results of the HSI analyses suggest that Alternative 1 depending on water year type and the application of a water temperature threshold in comparison to the No Action Alternative would likely have adverse to negligible impacts on juvenile Delta smelt summer and fall habitat. Results from the revised Maunder and Deriso life cycle model indicate that under Alternative 1 during the summer there may be a minor adverse impact on post-larval survival and during the fall no impact on juvenile Delta smelt survival compared to the No Action Alternative. Compared to the No Action Alternative, CPUE of Delta smelt prey species was not related to outflow in the summer and is expected to be slightly lower under Alternative 1 during the fall.

Potential Changes to Entrainment of Delta Smelt

Differences in flow between Alternative 1 and the No Action Alternative may affect the entrainment of juvenile Delta smelt. Entrainment varies annually and depends on a combination of hydrology, turbidity, and export rates (see Smith et al. 2021). Historic salvage shows juvenile Delta smelt are entrained in the Delta Fish Collection Facilities, however in more recent years fewer fish have been entrained likely due to a combination of changes to operations and the continued decline of the Delta smelt population. While the USFWS life cycle model does incorporate entrainment, it was not used to evaluate entrainment of juvenile Delta smelt. Instead, OMR flows were used to evaluate changes between Alternative 1 and the No Action Alternative.

CalSim3 OMR Values

OMR combined flows ranged from more negative to less negative under Alternative 1 when compared to the No Action Alternative from June to November, which would have adverse and beneficial effects on entrainment of juvenile Delta smelt (Table O-21). The largest difference in OMR flows under Alternative 1 compared with the No Action Alternative were in September during the above normal water year type (65% more negative), while OMR flows were less negative in November during the above normal water year type (17% less negative) compared to the No Action Alternative. In general, during the June to November period, OMR was more negative under Alternative 1 compared to the No Action Alternative in June, September and October, which would be detrimental; similar to the No Action Alternative in July and August, which would have negligible effects; and less negative in November, which would have beneficial effects.

Summary

Alternative 1 relative to the No Action Alternative is expected to have an adverse to beneficial impacts on the entrainment of juvenile Delta smelt due to differences in flow. In general, OMR flow was more negative under Alternative 1 compared to the No Action Alternative in June, September and October, which would be detrimental; similar to the No Action Alternative in July and August, which would have negligible impacts; and less negative in November, which may be beneficial.

O.4.13 Longfin Smelt

O.4.13.1 Bay Delta

Adult Migration and Spawning

Longfin smelt are anadromous and spawn in fresh or low-salinity water in the Bay-Delta (Grimaldo et al. 2017), generally at two years of age (Moyle 2002). A portion of the population migrate from the ocean into the San Francisco Estuary and move upstream to spawn during late fall through winter, with most spawning occurring from November through April (California Department of Fish and Wildlife 2009a). Spawning locations have been estimated using field observations of gravid females and yolk-sac larvae (Grimaldo et al. 2017, Lewis et al. 2019) and through particle-tracking modeling (Gross et al. 2022) to suggest spawning extends farther seaward than previously thought (Moyle 2002). Based on these studies, longfin smelt appear to spawn in the low-salinity zone where brackish and freshwaters meet (Grimaldo et al. 2017), and in tidal wetlands of south San Francisco Bay and San Pablo Bay when hydrological conditions favor spawning in more seaward regions (Lewis et al. 2020, Grimaldo et al. 2020). These regions include marshes of the Petaluma watershed, Napa-Sonoma watershed, Sacramento-San Joaquin watershed, and Coyote Creek watershed (Lewis et al. 2020, Hobbs et al. 2015).

Potential Changes to Longfin Smelt from Seasonal Operations

Differences in flows under Alternative 1 compared with the No Action Alternative may have effects on adult migrating and spawning longfin smelt including X2 position and prey availability. These possible differences were evaluated.

<u>CalSim3 Modeled X2 Position</u>

Longfin smelt utilize low salinity zone (LSZ, 0.5–6 psu) habitat for spawning and rearing (Grimaldo et al. 2017, Merz et al. 2013, Hobbs et al. 2010). X2 (the distance of 2 psu salinity isohaline from the Golden Gate Bridge) has been used as a proxy for the LSZ (MacWilliams et al. 2015, Kimmerer et al. 2013, Jassby et al. 1995). The position of X2 responds to CVP and SWP operations, the more freshwater outflow into the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position.. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and at the confluence of the Sacramento and San Joaquin Rivers (X2 ~ 80-85 km).

The position of X2 under Alternative 1 was similar to the No Action Alternative (Table O-18) during the adult longfin smelt migration and spawning period, only varying one to three km from the No Action Alternative, likely having negligible impacts on adult longfin smelt in the winter and spring. However, there is likely a negative impact during wet and above normal years on adult longfin smelt during the fall since the position of X2 will be further landward in September and October.

Zooplankton CPUE-Outflow Analysis

For the zooplankton CPUE-Outflow analysis, for each Delta smelt prey taxon, mean annual loge-transformed catch per unit effort + 1 for each taxon was regressed against mean annual loge-transformed Delta outflow for each seasonal period. Statistically significant regressions were then applied to the 1922-2021 CalSim 3-modeled data for Baseline Conditions and Proposed Action scenarios, with predictions back-transformed to the original measurement scale (catch per unit effort, number per cubic meter) for summary of results.

Analysis of CPUE with outflow during the fall showed significant relationships for two taxa; *E. affinis* adults and mysids. Under Alternative 1, when compared to the No Action Alternative, for *E. affinis* there was no expected change in CPUE in the below normal and critically dry water year types and the largest decrease of 67% during the above normal water year type. However, the expected CPUE for *E. affinis* during the fall was very low (one to three individuals per cubic meter) and unlikely to impact longfin smelt. For mysids, there was no expected change in CPUE in the dry and critically dry water year types and the largest decrease of 42% was during the above normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most fall months and water year types, (Table O-20) resulting in lower zooplankton CPUE.

Analysis of catch per unit effort (CPUE) with outflow during the winter in the low salinity zone showed significant relationships for 5 zooplankton taxa; *Daphnia* adults, decapod larvae, *E. affinis* adults, other calanoid copepod adults, other calanoid copepodites. Under Alternative 1, when compared to the No Action Alternative, *Daphnia* adult CPUE was not expected to change in the wet, below normal, and critically dry water year types. *Daphnia* adult CPUE had the largest expected decrease of 14% during the dry water year type. Results for decapod larvae were negligible when rounded to the nearest whole integer (values were 0) across all WYT and scenarios. *Eurytemora affinis* (adults) CPUE, had the smallest expected decrease of 1% during the wet water year type, and the largest decrease of 12% during the critically dry water year type. For other calanoid copepod adult CPUEs (*Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), the smallest expected decrease of 3% was during the wet water year type and the largest expected decrease of 33% was during dry water year type. For other calanoid copepod copepodites (*Acartia* spp., *Acartiella* spp., unidentified calanoids, *Eurytemora affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), CPUE was expected to decrease 2% during the wet water year types and 16% during the critically dry water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most winter months and water year types (Table O-20) resulting in lower zooplankton CPUE.

Analysis of CPUE with outflow during the spring showed significant relationships for the five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. Under Alternative 1, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 13% during the critically dry water year type and the largest expected CPUE decrease of 8% during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the above normal and below normal water year type. Harpacticoids had the largest

expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the below normal water year type. Other calanoid adults had the largest expected CPUE increase of 8% during the critically dry water year type and the largest expected CPUE decrease of 6% during the above normal and below normal water year type. Other calanoid copepodites had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 4% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most spring months and water year types, except in April during the critically dry water year type (Table O-20) resulting in lower zooplankton CPUE in all other water year types but an increase in the CPUE during the critically dry water year type compared to the No Action Alternative.

Summary

Alternative 1 relative to the No Action Alternative is expected to have adverse impacts on adult longfin smelt migration and spawning due to differences in flow. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to decrease under Alternative 1 particularly during the winter and spring. CalSim3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the winter and spring which are expected to have a negligible impact on adult longfin smelt migration and spawning but did increase landwards in September and October of wet and above normal water year types which may adversely impact adult longfin smelt when compared to the No Action Alternative.

Potential Changes to Entrainment of Longfin Smelt

Differences in flow between Alternative 1 and the No Action Alternative may affect the entrainment of adult longfin smelt. Entrainment varies annually and depends on a combination of hydrology and export rates.

CalSim3 Modeled X2 Position

Modeling analysis of adult longfin salvage presented in CDFW (2020) predicted increased adult salvage when X2 was near 65 km and when X2 was beyond 75 km. During periods of high outflow adult longfin smelt are less likely to be entrained because the low salinity zone is further away from the Delta, and more individuals may spawn in areas where freshwater flow creates ideal spawning environments. The increase in salvage when X2 was at 65 km is believed to be due to adult longfin staging in Suisun Bay before migrating into the Delta.

The position of X2 under Alternative 1 was similar to the No Action Alternative (Table O-18) during the adult longfin smelt migration and spawning period, only varying one to three km from the No Action Alternative, likely having negligible impacts on entrainment of adult longfin smelt. However, there is likely an adverse impact during wet and above normal years on adult longfin smelt during the fall since the position of X2 will be further landward in September and October when compared to the No Action Alternative.

CalSim3 Total Exports and OMR Values

An effects analysis of adult longfin smelt entrainment at CVP and SWP facilities found that salvage was increased with fish proximity to the facilities and the magnitude of negative OMR flows caused by the export facilities (CDFW 2020). The analysis noted that this is an additive effect; salvage only increased when multiple factors (e.g. increased proximity to export facilities, high exports, and highly negative OMR) were considered. The model predicted the magnitude of salvage events increased when total Delta exports increased and when OMR values were more negative than -5000 cfs, however the analysis was not able to identify the underlying mechanisms for the -5000 cfs threshold.

Total exports during the adult longfin smelt migration and spawning period under Alternative 1 tended to increase when compared to the No Action Alternative, except in November (Table O4.8). OMR combined flows were also more negative under Alternative 1 compared to the No Action Alternative and more negative the -5000 cfs threshold for all water year types during the months of December, January and February (Table O-21). Compared to the No Action Alternative, under Alternative 1, there is likely an adverse impact on adult longfin smelt during the winter season when compared to the No Action Alternative since total exports are higher and OMR values were more negative than -5000 cfs.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible to adverse impacts on entrainment of adult longfin smelt during migration and spawning due to differences in flow. Compared to the No Action Alternative, the position of X2 only varied one to three km under Alternative 1, likely having a negligible impact on adult longfin smelt in winter and spring. There is likely an adverse impact during wet and above normal years on adult longfin smelt during the fall since the position of X2 will be further landward in September and October when compared to the No Action Alternative. There is likely an adverse impact on adult longfin smelt during the winter season when compared to the No Action Alternative since total exports are higher and OMR values were more negative than -5000 cfs.

Eggs and Larvae

In the San Francisco Estuary, most longfin smelt larvae hatch between December and May, and rarely outside of this range (Baxter 1999). Longfin smelt larvae are most abundant in the water column usually from January through April (Bureau of Reclamation 2008). Larval longfin smelt rear in low salinity to brackish water (2–12 ppt; Grimaldo et al. 2017) and in tidal wetlands of San Pablo Bay (Sonoma Creek, Napa River, and Petaluma River) and south San Francisco Bay (Alviso Marsh Complex and salt pond restoration areas) (Hobbs et al. 2015, Lewis et al. 2020). The spatial distribution of these larvae reflects the year-to-year variation in freshwater outflow which affects the geographic location of the low-salinity zone during the winter and spring (Dege and Brown 2004, Grimaldo et al. 2020). During high outflow years, the low salinity zone can extend into San Pablo Bay. Within the low-salinity zone and adjacent waters, larvae have been commonly collected in both littoral (nearshore) and pelagic (offshore) habitats.

Potential Changes to Longfin Smelt from Seasonal Operations

Differences in flows under Alternative 1 compared with the No Action Alternative may have effects on longfin smelt larvae including X2 position and prey availability. These possible differences were evaluated using a quantitative model.

CalSim3 X2 Modeled X2 Position

Longfin smelt utilize low salinity zone (LSZ, 0.5–6 psu) habitat for spawning and rearing (Grimaldo et al. 2017, Merz et al. 2013, Hobbs et al. 2010). X2 (the distance of 2 psu salinity isohaline from the Golden Gate Bridge) has been used as a proxy for the LSZ (MacWilliams et al. 2015, Kimmerer et al. 2013, Jassby et al. 1995). The position of X2 responds to CVP and SWP operations, the more freshwater outflow into the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and at the confluence of the Sacramento and San Joaquin Rivers (X2 ~ 80-85 km).

The position of X2 under Alternative 1 was similar to the No Action Alternative (Table O-18) during the larval longfin smelt period, only varying 1-3 km from the No Action Alternative, likely having negligible impacts on larval longfin smelt in the winter and spring.

Zooplankton CPUE-Outflow Analysis

Analysis of catch per unit effort (CPUE) with outflow during the winter in the low salinity zone showed significant relationships for 5 zooplankton taxa; *Daphnia* adults, decapod larvae, *Eurytemora affinis* adults, other calanoid adults, and other calanoid copepodites. Under Alternative 1, when compared to the No Action Alternative, *Daphnia* adult CPUE was not expected to change in the wet, below normal, and critically dry water year types. *Daphnia* adult CPUE had the largest expected decrease of 14% during the dry water year type. Results for decapod larvae were negligible when rounded to the nearest whole integer (values were 0) across all WYT and scenarios. *Eurytemora affinis* (adults) CPUE, had the smallest expected decrease of 1% during the wet water year type, and the largest decrease of 12% during the critically dry water year type. For other calanoid copepod adult CPUEs (*Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), the smallest expected decrease of 3% was during the wet water year type and the largest expected decrease of 33% was during dry water year type. For other calanoid copepod copepodites (*Acartia* spp., *Acartiella* spp., unidentified calanoids, *Eurytemora affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), CPUE was expected to decrease 2% during the wet water year types and 16% during the critically dry water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most winter months and water year types (Table O-20) resulting in lower zooplankton CPUE.

Analysis of CPUE with outflow during the spring showed significant relationships for the five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. Under Alternative 1, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 13% during the critically dry water year type and the largest expected CPUE decrease of 8%

during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the above normal and below normal water year type. Harpacticoids had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the below normal water year type. Other calanoid adults had the largest expected CPUE increase of 8% during the critically dry water year type and the largest expected CPUE decrease of 6% during the above normal and below normal water year type. Other calanoid copepodites had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 4% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most spring months and water year types, except in April during the critically dry water year type (Table O-20) resulting in lower zooplankton CPUE in all other water year types but an increase in the CPUE during the critically dry water year type compared to the No Action Alternative.

Summary

Alternative 1 relative to the No Action Alternative is expected to have both adverse and beneficial impacts on longfin smelt larvae due to differences in flow. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to increase under Alternative 1 during the spring for the critically dry water year type but decrease in all other water year types. CalSim3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the winter and spring which are expected to have negligible impacts on larval longfin smelt.

Potential Changes to Entrainment of Longfin Smelt

Differences in flows under Alternative 1 compared with the No Action Alternative may have impacts on entrainment of longfin smelt larvae.

Particle Tracking Model (PTM)

The CalSim 3 model simulated operational conditions under a range of OMR and inflow conditions from the Sacramento and San Joaquin rivers, with the DSM2 PTM module allowing for an assessment of entrainment of surface-oriented or neutrally buoyant passive particles (proxies for larval longfin smelt) at export facilities (Attachment I.8, *Particle Tracking Fate Modeling of Larval Smelt Entrainment*).

PTM analysis was only considered for the larval longfin smelt life stage since modeling suggests larger larvae (>16mm) likely transition from passive to active behavior as they grow larger, undergoing tidal vertical migration to maintain horizontal position in the estuary (Gross et al. 2022, Bennett et al. 2002). Moreover, field studies have demonstrated clear ontogenetic patterns of vertical distribution in larval longfin smelt, closely tracking swim-bladder development. Yolk-sac larvae and younger postlarvae <10mm in length appear primarily surface-oriented, while longfin smelt >10mm distribute throughout the water column (Bennet et al. 2002). As such, PTM model outputs for both surface-oriented (SO) and neutrally buoyant (NB) particles are presented. Results discussed here are expressed as percent of particles with a fate of *Entrained at Exports*. Please refer to Attachment I.3, *Delta Export Zone of Influence Analysis*, for keys to inflow and

OMR bins codes, including corresponding Sacramento and San Joaquin River flow ranges and mean OMR and Exports flow ranges. The following narrative focuses on three injection regions when assessing potential entrainment effects from the perspective of varying inflows (Inflow bins: *Sacramento River, Western Delta*, and *Yolo Bypass Region*) and three injection regions when assessing potential effects from the perspective of OMR net flows (OMR bins: *Central Delta, Mokelumne River and Yolo Bypass Region*).

Inflow Bins.

Depending on inflow conditions, an average of 2 to 28% of SO particles or 2 to 25% of NB particles injected within the Sacramento River region would be entrained at export facilities under Alternative 1, compared to 1 to 16% (SO) and 1 to 13% (NB) respectively, under the No Action Alternative. Regardless of inflow conditions, the average percentage of particles entrained at exports under Alternative 1 was always higher than under the No Action Alternative, ranging from +18% (SO) or 21% (NB) under "lohi" conditions to +277% under "himed" conditions (SO) or +294% under "hilo"conditions (NB).

Depending on inflow conditions, an average of 0 to 8% of SO particles or 0 to 6% of NB particles injected within the Western Delta region would be entrained at export facilities under Alternative 1, compared to 0 to 4% (SO) and 0 to 3% (NB) respectively, under the No Action Alternative. The average percentage of particles entrained at exports ranged from 4% lower for Alternative 1 than for the No Action Alternative under "lohi" inflow conditions to 2262% higher under "hihi" inflow conditions for SO particles, and from +1% under "lolo" and "lohi" conditions to +6244% under "hihi" conditions for Alternative 1 compared to the No Action Alternative for NB particles. However, note that the overall percentage of particles entrained would remain extremely low in such conditions (close to 0 for both Alternative 1 and the No Action Alternative).

Depending on inflow conditions, an average of 0 to 14% of SO particles or 0 to 11% of NB particles injected within the Yolo Bypass region would be entrained at export facilities under Alternative 1, compared to 0 to 8% (SO) and 0 to 5% (NB respectively, under the No Action Alternative. Regardless of inflow conditions, the average percentage of particles entrained at exports under Alternative 1 was always higher than under the No Action Alternative, ranging from +12% (SO) or +26% (NB) under "lohi" conditions to +517% (SO) or +659% (NB) under "himed" conditions.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of inflow conditions, there was a difference between the average percentage of particles entrained under Alternative 1 and under the No Action Alternative (-2 to +9% NB and SO).

OMR bins.

Depending on OMR flow conditions, an average of 22 to 58% (SO) or 20 to 58% (NB) of particles injected within the Central Delta region would be entrained at export facilities under Alternative 1, compared to 24 to 81% (SO) and 22 to 79% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 28% lower (SO) or 27%

lower (NB) under Alternative 1 than under the No Action Alternative for the -5500 OMR bin to 34% higher (SO) or 36% higher (NB) for the -2000 OMR bin.

Depending on OMR flow conditions, an average of 26 to 73% (SO) or 24 to 72% (NB) of particles injected within the Mokelumne River region would be entrained at export facilities under Alternative 1, compared to 23 to 78% (SO) and 21 to 75% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 6% (SO) or 4% (NB) lower under Alternative 1 than under the No Action Alternative for the -5500 OMR bin to 34% (SO) or 36% (NB) higher for the -3500 OMR bin.

Depending on OMR flow conditions, an average of 3 to 7% (SO) or 2 to 6% (NB) of particles injected within the Yolo Bypass region would be entrained at export facilities under Alternative 1, compared to 2 to 16% (SO) and 1 to 13% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 57% lower (SO) or 58% lower (NB) under Alternative 1 than under the No Action Alternative for the -5500 OMR bin to 200% higher (SO) or 228% higher (NB) for the -3500 OMR bin.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of OMR flow conditions, there was generally little difference between the average percentage of particles entrained under Alternative 4 and under the No Action Alternative (-2 to +2% NB and SO).

Summary

The percentage of particles entrained at exports were generally similar between surface-oriented particles representative of yolk-sac larval longfin smelt and neutrally buoyant particles representative of >10mm larval longfin smelt. For injection regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta) Alternative 1 relative to the No Action Alternative is expected to have an small adverse to negligible impact depending on inflow groupings on the entrainment of larval longfin smelt due to differences in flow. For injection regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), Alternative 1 is expected to have a similar impact on entrainment of larval longfin smelt compared to the No Action Alternative for all OMR groupings.

Juveniles

Juveniles have been detected throughout the San Francisco Estuary and rarely in some Delta tributaries (Merz et al. 2013). Juveniles gradually move seaward as they grow and as water temperatures increase in the late spring and early summer (Rosenfield and Baxter 2007; Tobias and Baxter 2021). Seasonal patterns in abundance and occurrence in the nearshore ocean suggest that the population is at least partially anadromous (Rosenfield and Baxter 2007; Garwood 2017). The detection of longfin smelt within the estuary throughout the year and geochemical analysis of otoliths suggests longfin smelt in the San Francisco Estuary utilize several life history strategies (Lewis et al. 2019).

Potential Changes to Longfin Smelt from Seasonal Operations

Differences in flows under Alternative 1 compared with the No Action Alternative may have effects on juvenile longfin smelt including X2 position, abundance and prey availability.

CalSim3 X2 Modeled X2 Position

The position of X2 under Alternative 1 was similar to the No Action Alternative (Table O-18) during the juvenile longfin smelt period, only varying 1-3 km from the No Action Alternative, likely having negligible impacts on juvenile longfin smelt in the spring and summer.

Longfin Smelt Abundance—Outflow Analysis

Juvenile Longfin Smelt abundance as represented by the Fall Midwater Trawl index of abundance is predicted to be between 5% to 10% lower, depending on the water year type, under Alternative 1 than it is for the No Action Alternative (Attachment J.1, *Longfin Smelt Outflow*, Table 3). The largest difference under Alternative 1 is predicted during above normal water years (10% lower under Alternative 1), and the smallest difference in predicted abundance results during critically dry water years (5% lower).

Zooplankton CPUE—Outflow Analysis

Analysis of CPUE with outflow during the spring showed significant relationships for the five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. Under Alternative 1, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 13% during the critically dry water year type and the largest expected CPUE decrease of 8% during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the above normal and below normal water year type. Harpacticoids had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 5% during the below normal water year type. Other calanoid adults had the largest expected CPUE increase of 8% during the critically dry water year type and the largest expected CPUE decrease of 6% during the above normal and below normal water year type. Other calanoid copepodites had the largest expected CPUE increase of 6% during the critically dry water year type and the largest expected CPUE decrease of 4% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 1 are generally lower than the No Action Alternative for most spring months and water year types, except in April during the critically dry water year type (Table O-20) resulting in lower zooplankton CPUE in all other water year types but an increase in the CPUE during the critically dry water year type compared to the No Action Alternative.

During the summer months (May to August), the zooplankton-outflow analysis showed no significant relationships between outflow and zooplankton CPUE. Several studies have previously found relationships between abundance of zooplankton taxa and outflow during the summer (e.g. Kimmerer 2002; Kimmerer et al. 2018) while other studies have found mixed effects (Frantzich et al. 2021) or no effects (Sommer et al. 2020) of increased flow on zooplankton abundance. Evaluating any possible benefits of increased outflow and flow pulses during summer may be difficult given sampling frequency and the effect size of increases to zooplankton abundances (Brandon et al. 2021).

Summary

Alternative 1 relative to the No Action Alternative is expected to have adverse impacts on juvenile longfin smelt due to differences in flow. Juvenile longfin smelt abundance, as represented by the Fall Midwater Trawl index of abundance, is predicted to be lower under Alternative 1 than it is for the No Action Alternative. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to decrease under Alternative 1 during the spring. CalSim3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the spring and summer which are expected to have negligible impacts on juvenile longfin smelt.

Potential Changes to Entrainment of Longfin Smelt

Differences in flows under Alternative 1 compared with the No Action Alternative may have effects on entrainment of juvenile longfin smelt. These possible differences were evaluated using a quantitative model.

Longfin Smelt Outflow Entrainment

Differences in flow between Alternative 1 compared with the No Action Alternative could have an effect on the entrainment of juvenile Longfin Smelt.

The regression from Grimaldo et al. (2009) between April-May juvenile longfin smelt entrainment and Old and Middle River flows was used to assess potential differences in salvage between modeled alternatives. The analysis does not account for changes in operations since the USFWS 2008 and 2009 Biological Opinion, changes in population size over time, turbidity, juvenile behavior, and geographic shifts in distribution during higher outflow years.

Changes in OMR flows under Alternative 1 compared with the No Action Alternative may have an impact on LFS salvage. Compared to the No Action Alternative, predicted salvage increases ranged from 35% during the critically dry water year type to 295% during the above normal water year type. Alternative 1 had the most negative mean April-May OMR values compared to the No Action Alternative across all water year types and therefore the highest predicted salvage. Overall modeling for Alternative 1 suggests that longfin smelt salvage would increase when compared to the No Action Alternative. (Attachment I.4, *Longfin Smelt Salvage-OMR Relationship*).

Summary

Alternative 1 relative to the No Action Alternative is expected to have an adverse impact on the entrainment of longfin smelt due to differences in flow. Analysis of the relationship between longfin smelt entrainment and outflow found an increase in entrainment compared to the No Action Alternative particularly during the above normal water year type.

O.4.14 Fall-run and Late Fall-run Chinook Salmon ESU

O.4.14.1 Sacramento River

Spawning and Egg/Alevin Incubation

Fall-run Chinook salmon typically spawn in the Sacramento River, primarily between Keswick Dam and RBDD from October through December, with incubation occurring from October through April. Peak spawning time for late fall-run Chinook salmon generally is from January through April (National Marine Fisheries Service 2009a), with incubation typically lasting for approximately two to four months between April and June (Moyle 2002). See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 1, differences in mean spawning WUA are higher in wet and above normal water year types, and lower in below normal, dry, and critically dry water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 1 and the No Action Alternative is a 4.2% increase in above normal water years. The largest reduction in estimated spawning habitat is a -0.6% decrease in critically dry water year types.

The monthly median value of spawning WUA under Alternative 1 is similar to the No Action Alternative in September, October, and December and slightly higher in November (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are relatively similar in September and October, and slightly lower in November and December. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently highest in December when compared to other spawning months (Table O-14). These higher flows in December results in lower spawning WUA results because the fall-run spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of WUA spawning habitat analysis based on CalSim3 simulated flows suggest that Alternative 1 may have a minor (4.2%) increase in estimated spawning habitat during above normal water years when compared to the No Action Alternative in the mainstem upper Sacramento River. Out of the four months of potential fall-run Chinook salmon spawning, September and October have the highest estimated spawning WUA across all alternatives.

Fall-run Chinook Salmon: Redd Dewatering Analysis

Fall-run Chinook salmon mean redd dewatering potential under Alternative 1 increases from drier to wetter water year types, but the differences are modest (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). Most egg incubation of fall-run Chinook salmon occurs during winter and spring, when periodic storms and high runoff in wetter years result in increased flow fluctuations. In drier winters, flow fluctuations are reduced and fewer redds are dewatered. Differences in mean redd dewatering potential between Alternative 1 and the No Action Alternative are relatively small, except for a reduction of 26.6% under Alternative 1 in above normal water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The apparent magnitude of this relative difference is misleading because the absolute difference is 3.9%.

Overall, the results indicate that redd dewatering potential under Alternative 1 would be largely similar to results under the No Action Alternative, except in above normal water years when redd dewatering would be moderately lower under Alternative 1.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 235 for Keswick Dam and Table 236 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 238 for Keswick Dam and Table 239 for RBDD. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during December through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 241 for Keswick Dam and Table 242 for RBDD.

Results for the three analyses are summarized in Table O-74. Table O-74, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 42.1°F to 55°F spawning initiation range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at both Keswick Dam and RBDD (Table O-74). There were five and six combinations (25% to 30%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both Keswick Dam and RBDD. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero and one combinations (0% and 5.0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. These results suggest that there would be negative water temperature-related effects of Alternative 1 on fall-run Chinook salmon spawning initiation, but otherwise minimal effects to spawning and egg/alevin incubation.

Table O-74. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)
Unfavorable	5 (25.0%)	4 (20.0%)	2 (10.0%)	5 (25.0%)	4 (20.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	1 (5.0%)	1 (5.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	6 (30.0%)	1 (5.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
42.8°F–56°F RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	1 (5.0%)	1 (5.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Fall-run Chinook Salmon: Removal of Sacramento River Pulse Flows

There may be beneficial impacts of the removal of spring pulse flows component under Alternative 1 compared to the No Action Alternative on redd dewatering. However, redd surveys occur during the pulse flow period and redd dewatering has not been observed under the No Action Alternative.

Fall-run Chinook Salmon: Summary

The change in seasonal operations in the Sacramento River between Alternative 1 and the No Action Alternative are expected to have minor adverse impacts on fall-run Chinook salmon spawning habitat and incubation. Under Alternative 1, changes in flows may have a minor increase in spawning habitat area and, except in above normal years, may moderately decrease redd dewatering potential. Water temperatures were more unfavorable for spawning initiation, but similar for pathogen virulence and incubation and emergence compared to the No Action Alternative. Water temperatures are expected to have minimal impacts on fall-run Chinook salmon spawning and incubation and the frequency of pathogen virulence under Alternative 1.

Late Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 1, differences in mean spawning WUA are lower in all water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). There are no increases in estimated spawning habitat between Alternative 1 and the No Action Alternative. The largest reduction in estimated spawning habitat is a -7.4% decrease in above normal water year types.

The monthly median values of spawning WUA under Alternative 1 are similar to the No Action Alternative throughout the three spawning months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are also relatively similar across all three spawning months. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are highest in February but all three months are above 8,000 cfs (Table O-14). This results in spawning WUA results that are approximately the same across all three months because the late fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The WUA spawning habitat analysis based on CalSim3 simulated flows suggest that Alternative 1 may have a moderate (7.4%) decrease in estimated spawning habitat during above normal water years when compared to the No Action Alternative in the mainstem upper Sacramento River. The three months of potential late fall-run Chinook salmon spawning have similar estimated spawning WUA across all alternatives.

Late Fall-run Chinook Salmon: Redd Dewatering Analysis

The results for both the No Action Alternative and Alternative 1 show large and consistent variations in percentage of late fall-run Chinook salmon redds dewatered with water year type, varying from high redd dewatering in wet water years to low redd dewatering in critically dry water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation reflects flow conditions for the winter and spring months when late fall-run Chinook salmon spawning and incubation occurs. During wet winters and springs, periodic storms and

high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. Differences in mean redd dewatering potential between Alternative 1 and the No Action Alternative are generally small and mostly constitute increases under Alternative 1, with a maximum increase of 12.6% in above normal water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The apparent magnitude of this relative difference is misleading because the absolute difference is 2.3%.

Overall, the results indicate that redd dewatering potential under Alternative 1 would be largely similar to results under the No Action Alternative.

Late Fall-run Chinook Salmon: Water Temperatures Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 267 for Keswick Dam and Table 268 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 270 for Keswick Dam and Table 271 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 273 for Keswick Dam and Table 274 for below Clear Creek.

Results for the three analyses are summarized in Table O-75. Table O-75 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 42.1°F to 55°F spawning initiation range analysis, there were three month-water year type combinations (15.0% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable conditions at both locations (Table O-75). For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four and eight combinations (20.0% and 40.0%, respectively) with favorable results at Keswick Dam and Clear Creek, respectively. There were no combinations (0%) with unfavorable results at both locations. These results suggest that there would be positive water temperature-related effects of Alternative 1 on late fall-run Chinook salmon spawning initiation, egg incubation, and fry emergence, and no negative effects to these life stages.

Table O-75. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Below Keswick Dam							
Favorable	3 (15.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (15.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	1 (5.0%)	1 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Below Clear Creek							
Favorable	3 (15.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	2 (10.0%)	2 (10.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Below Clear Creek							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
42.8°F–56°F RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Below Keswick Dam							
Favorable	4 (20.0%)	4 (20.0%)	4 (20.0%)	4 (20.0%)	4 (20.0%)	4 (20.0%)	2 (10.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Below Clear Creek							
Favorable	8 (40.0%)	5 (25.0%)	5 (25.0%)	5 (25.0%)	5 (25.0%)	7 (35.0%)	4 (20.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Late Fall-run Chinook Salmon: Removal of Sacramento River Pulse Flows

There may be impacts of the removal of spring pulse flows component under Alternative 1 compared to the No Action Alternative on redd dewatering and spawning behavior. However, redd surveys occur during the pulse flow period and redd dewatering has not been observed under the No Action Alternative.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in the Sacramento River between Alternative 1 and the No Action Alternative are expected to have minor impacts on late fall-run Chinook salmon spawning habitat and incubation. Under Alternative 1, changes in flows may cause a moderate decrease in spawning habitat area in above normal water years, but redd dewatering would be similar to the conditions under the No Action Alternative. There may be beneficial impacts to spawning behavior with the removal of spring pulse flows. Water temperatures more favorable for spawning initiation, and egg incubation and fry emergence, but similar for pathogen virulence compared to the No Action Alternative. Water temperatures are expected to have minimal impacts on late fall-run Chinook salmon spawning and incubation or the frequency of pathogen virulence under Alternative 1. Alternative 1 would have negative impacts on spawning and incubation for late fall-run Chinook salmon.

Juvenile Rearing and Emigration

The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, mostly between January through June. Late fall-run Chinook salmon juveniles typically enter the ocean after seven to 13 months of rearing in freshwater, generally between October and February. See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under Alternative 1, mean fry rearing WUA increase in critically dry water year types and decrease in all other water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 0.1% increase in wet water year types. The largest reduction in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 2.6% decrease in above normal water year types.

The monthly median value of fry rearing WUA under Alternative 1 has a 12% reduction in February below the No Action Alternative but is similar throughout the other fry rearing months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The results during December, January, and March show little variation in the third quartile of the WUA distributions. This occurs because the fry rearing WUA curves peak at the lowest flows encountered in the river (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and Keswick Dam flow releases are frequently low during these months in critically dry years when Shasta Reservoir is operated to rebuild storage volume (Table O-14). The first quartile is much wider because a greater range of flows affect the fry rearing WUA values below the median.

The results of the fall-run Chinook salmon fry rearing habitat analysis suggest that Alternative 1 in comparison to the No Action Alternative may have a minor (less than 3%) decrease in estimated juvenile rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in February (12%) in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Fall-run Chinook Salmon: Juvenile Rearing Habitat Analysis

Under Alternative 1, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). There are no increases in mean juvenile rearing WUA under Alternative 1 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 2.0% decrease in critically dry water year types.

The monthly median value of estimated juvenile rearing WUA under Alternative 1 is 7% lower than the No Action Alternative in June but similar February through May (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The estimated juvenile rearing WUA values under the modeled alternatives are similar across the months of February and March, and gradually decrease until the lowest estimated values in June. As discussed previously for fry rearing WUA, the high WUA values with low variability in the third quartile for December through March result from the peaking of the WUA curve at the lowest flows and frequent low Keswick Dam flow releases during these months to build Shasta Reservoir storage (Table O-14). The wide range of values in the first quartile of these months reflects the high frequency and variability of higher flows in these wet months. The lowest juvenile rearing WUA values in June result from releases in the summer months above 10,000 cfs and estimated peak juvenile rearing at flows below 5,000 cfs.

The results of the fall-run Chinook salmon juvenile rearing habitat analysis suggest that Alternative 1 in comparison to the No Action Alternative may have a minor (less than 2.5%) decrease in estimated juvenile rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in June (7%) in the mainstem upper Sacramento River.

Fall-run Chinook Salmon: Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Alternative 1 shows a substantial but inconsistent increase in stranding of fall-run Chinook salmon fry from critically dry to wet water year types, with a minor reduction in stranding from dry to below normal water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Fall-run fry rearing occurs primarily during winter and early spring. Alternative 1 shows the highest stranding in February, the lowest stranding in March, and similar stranding in December and January (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher mean stranding levels for fall-run Chinook salmon fry during February and wet water year types generally likely results because of periodic storms and high runoff that produce increased variability of flow. Alternative 1 has higher juvenile stranding of fall-run fry than the No Action Alternative in all water year types except critically dry water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The largest difference is a 19.0% increase for above normal water years and the largest reduction is 13.7% in critically dry water.

Overall, fall-run Chinook salmon juvenile stranding for fry is higher under Alternative 1 in comparison to the No Action Alternative.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 247 for Keswick Dam, Table 248 for Red Bluff Diversion Dam, and Table 249 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 251 for Keswick Dam, Table 251 for Red Bluff Diversion Dam, and Table 253 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 255 for Keswick Dam, Table 256 for Red Bluff Diversion Dam, and Table 257 for Hamilton City.

Results for the three analyses are summarized in Table O-76. Table O-76., as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F juvenile optimum temperature range under Alternative 1, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-76). There were zero to six combinations (0% to 30.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 1, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to 12 combinations (0% to 60.0%) with favorable results depending on location. There would be no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive and negative water temperature-related effects of Alternative 1 on fall-run Chinook salmon juvenile rearing and emigration.

Table O-76. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	6 (30.0%)	3 (15.0%)	3 (15.0%)	3 (15.0%)	3 (15.0%)	6 (30.0%)	2 (10.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)
Unfavorable	1 (5.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F JUVENILE PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	12 (60.0%)	10 (50.0%)	9 (45.0%)	7 (35.0%)	7 (35.0%)	5 (25.0%)	2 (10.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (10.0%)	2 (10.0%)
Hamilton City							
Favorable	2 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Fall-run Chinook Salmon: Removal of Sacramento River Pulse Flows

There may be adverse and beneficial impacts from the removal of spring pulse flows component under Alternative 1 compared to the No Action Alternative. There may be beneficial impacts from reduced fry stranding and predation. There may be adverse impacts from increased travel time for juvenile outmigration.

Fall-run Chinook Salmon: Summary

Under Alternative 1, differences in seasonal operations in the Sacramento River are largely expected to have minor impacts on fall-run Chinook salmon fry and juvenile rearing habitat and behavior. There would be minor decreases in WUA for fall-run Chinook salmon fry rearing in all water year types relative to the No Action Alternative, with the greatest difference occurring in above normal water year types. February would experience the greatest reduction in fry rearing WUA, relative to all other months. There would also be a minor decrease in juvenile rearing habitat in all water year types, predominantly in June when most of the juveniles have already outmigrated. Fry stranding would be increased up to 19%, particularly in February, and in wet water year types compared to the No Action Alternative. Fry stranding may be reduced with the removal of the spring pulse flows component. There may be increased travel times for juvenile outmigration without spring pulse flow events. Fall-run Chinook salmon rearing fry and juveniles would experience more unfavorable water temperature conditions below Keswick Dam and near the RBDD for growth, smoltification, and vulnerability to predators, but more favorable conditions for juveniles with regards to pathogen virulence below RBDD. Differences in temperatures are expected to have a moderate impact on fall-run Chinook salmon rearing and emigration.

Late Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under Alternative 1, mean fry rearing WUA increase in wet and above normal water year types and decreases in all other water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 1.3% increase in above normal water year types. The largest reduction in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 3.5% decrease in critically dry water year types.

The monthly median value of fry rearing WUA under Alternative 1 is 8% lower than the No Action Alternative in April but similar in March, May, and June (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The median fry rearing WUA values under the modeled alternatives are similar across the months of May and June, and highest in March. The lower fry rearing WUA values in May and June result from releases in the summer months above 7,000 cfs (Table O-14) and estimated peak fry rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the late fall-run Chinook salmon fry rearing habitat analyses indicate that Alternative 1 in comparison to the No Action Alternative may have a minor (up to 4%) increase and/or decrease in estimated fry rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in April (8%) in the mainstem upper Sacramento River.

Late Fall-run Chinook Salmon: Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Mean stranding of late fall-run Chinook salmon fry under Alternative 1 shows minor and inconsistent variation with water year type; wet years have the highest stranding and dry years the lowest, while standing in critically dry years is next highest after wet years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Late fall-run Chinook salmon fry rearing occurs primarily during the spring months. Alternative 1 shows the highest stranding in March, the lowest stranding in May, and similar stranding in April and June (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Differences in late fall-run Chinook salmon juvenile stranding between Alternative 1 and the No Action Alternative are large, ranging from reductions of 17.0% and 16.5% for below normal and dry water year types, respectively, to increases of 21.3% and 26.3% for above normal and critically dry water years, respectively (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, late fall-run Chinook salmon juvenile stranding for fry is higher under Alternative 1 in comparison to the No Action Alternative, although results vary greatly depending on water year type.

Late Fall-run Chinook Salmon: Juvenile Rearing Habitat Analysis

Under Alternative 1, mean juvenile rearing WUA constitute increases in below normal water year types and reductions in all other water year types in comparison to the No Action Alternative (See Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 0.6% increase in below normal water year types. The largest reduction in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 2.1% decrease in critically dry water year types.

On a monthly scale, the median value of estimated juvenile rearing WUA under Alternative 1 is 7% lower than the No Action Alternative in June but similar (less than a 5% difference) in the other juvenile rearing months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). During the juvenile rearing period, the median WUA values steadily decline from May to the lowest median WUA values in July. The highest median WUA values occur in September across all alternatives. The lower juvenile rearing WUA values in June and July result from releases in the summer months above 7,000 cfs (Table O-14) and estimated peak juvenile rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the late fall-run Chinook salmon juvenile rearing habitat analyses indicate that Alternative 1 in comparison to the No Action Alternative may have a minor (less than 2.5%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in June (7%) in the mainstem upper Sacramento River.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 279 for Keswick Dam, Table 280 for Red Bluff Diversion Dam, and Table 281 for Hamilton City. Full results of the analysis assessing the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 283for Keswick Dam, Table 284 for Red Bluff Diversion Dam, and Table 285 for Hamilton City. Full results of the analysis assessing the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 287 for Keswick Dam, Table 288 for Red Bluff Diversion Dam, and Table 289 for Hamilton City.

Results for the three analyses are summarized in Table O-77. Table O-77, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F juvenile optimum temperature range under Alternative 1, there were two to five month-water year type combinations (3.6% to 9.1% of total combinations during the period) with favorable results depending on location (Table O-77). There were zero to six combinations (0% to 10.9%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 1, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to 13 combinations (0% to 23.6%) with favorable results depending on location. There would be zero to five combinations (0% to 9.1%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 1 on late fall-run Chinook salmon juvenile rearing and emigration.

Combined, results of these analyses indicate that there would be both positive and negative water temperature-related effects of Alternative 1 on late fall-run Chinook salmon juvenile rearing and emigration in the Sacramento River.

Table O-77. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Below Keswick Dam							
Favorable	2 (3.6%)	2 (3.6%)	2 (3.6%)	4 (7.3%)	2 (3.6%)	0 (0.0%)	0 (0.0%)
Unfavorable	6 (10.9%)	3 (5.5%)	5 (9.1%)	3 (5.5%)	3 (5.5%)	8 (14.5%)	5 (9.1%)
Red Bluff Diversion Dam							
Favorable	5 (9.1%)	0 (0.0%)	0 (0.0%)	1 (1.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (3.6%)	2 (3.6%)	1 (1.8%)	1 (1.8%)	3 (5.5%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	4 (7.3%)	1 (1.8%)	2 (3.6%)	1 (1.8%)	1 (1.8%)	3 (5.5%)	2 (3.6%)
Unfavorable	0 (0.0%)	1 (1.8%)	1 (1.8%)	1 (1.8%)	2 (3.6%)	1 (1.8%)	2 (3.6%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F JUVENILE PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	3 (5.5%)	0 (0.0%)	0 (0.0%)	3 (5.5%)	3 (5.5%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.8%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	13 (23.6%)	14 (25.5%)	13 (23.6%)	11 (20.0%)	11 (20.0%)	11 (20.0%)	7 (12.7%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (3.6%)	3 (5.5%)
Hamilton City							
Favorable	2 (3.6%)	0 (0.0%)	1 (1.8%)	0 (0.0%)	2 (3.6%)	1 (1.8%)	1 (1.8%)
Unfavorable	5 (9.1%)	0 (0.0%)	0 (0.0%)	1 (1.8%)	0 (0.0%)	3 (5.5%)	1 (1.8%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Late Fall-run Chinook Salmon: Removal of Sacramento River Pulse Flows

There may be adverse and beneficial impacts from the removal of spring pulse flows component under Alternative 1 compared to the No Action Alternative. There may be beneficial impacts from reduced fry stranding and predation. There may be adverse impacts from increased travel time for juvenile outmigration.

Late Fall-run Chinook Salmon: Summary

Under Alternative 1, differences in seasonal operations in the Sacramento River are largely expected to have minor impacts on late fall-run Chinook salmon fry and juvenile rearing habitat and behavior. There would be minor differences in WUA for late fall-run Chinook salmon fry rearing in all water year types relative to the No Action Alternative. April would experience the greatest reduction in fry rearing WUA, relative to all other months. Fry stranding would overall increase under Alternative 1. Fry stranding may be reduced with the removal of the spring pulse flows component. There may be increased travel times for juvenile outmigration without spring pulse flow events. Late fall-run Chinook salmon fry and juveniles would experience both favorable and unfavorable water temperature conditions below Keswick Dam and near the RBDD for growth, smoltification, and vulnerability to predators, and more favorable conditions protecting them from virulent pathogens. Differences in water temperatures are expected to have minor adverse and minor beneficial impacts on late fall-run Chinook salmon rearing and emigration.

Adult Upstream Migration and Holding

Fall-run Chinook salmon migrate upstream past RBDD on the Sacramento River from July to December, and late fall-run Chinook salmon migrate upstream past RBDD from October through December (National Marine Fisheries Service 2009a). Adult late fall-run Chinook salmon typically hold in the river for one month to three months before spawning, while fall-run Chinook salmon generally spawn shortly after entering freshwater. See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling indicates that the average of all simulated flow releases below Keswick Dam during the adult migration and holding period would be generally highest in July and lowest in October and November under Alternative 1 (Table O-14). Wet and above normal water year types experience the greatest increases in average monthly flows in December (28%), the greatest decreases average monthly flows in August, September, and November (-7 to -20%). Below normal water year types show a substantial increase in average monthly flows in September (12%), with a substantial decrease in average monthly flows in August (-9%). Critically dry water year types have the largest average monthly flow increases during the adult

migration period in July (12%), but negligible average annual flow decreases (-3% or less). Average monthly flows are expected to increase by more than 5% in December, but the average monthly flows would be similar in all other months (less than 5% difference).

At RBDD, CalSim 3 modeling indicates that the average of all simulated flows during the adult migration period are generally highest in July and December, and lowest in September through November under Alternative 1 compared to the No Action Alternative (Table O-15). The greatest percent increase in average monthly flows would occur in June of wet, above normal and below normal water year types, with the increases ranging from 6 to 12%. August and September would experience the largest flow decreases ranging between -5 and -21% for wet and above normal water year types for both months, and also for below normal water year types for August. Average monthly flows are expected to decrease by more than 5% in August and September, but the average monthly flows would be similar in all other months. The average monthly flows across all water year types under Alternative 1 between June and December would be greater than 5,500 cfs at Wilkins Slough, greater than 7,500 cfs at Hamilton City, greater than 9,000 cfs at RBDD, and greater than 8,000 cfs at Keswick Dam (Table O-14 through Table O-17). Flows at in the Sacramento River under Alternative 1 would be high enough (> 3,250 cfs) to allow upstream passage.

Removal of Sacramento River Pulse Flows

Fall-run and late fall-run adult migration is outside the spring pulse flow period.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 227 for Keswick Dam, Table 228 for Red Bluff Diversion Dam, and Table 229 for Hamilton City. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 231 for Keswick Dam, Table 232 for Red Bluff Diversion Dam, and Table 233 for Hamilton City.

Results are summarized in Table O-78. Table O-78, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 37.9°F to 68°F successful adult migration range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-78). There were zero to two combinations (0% to 6.7%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to one combinations (0% to 3.3%) with favorable results and zero to five combinations (0% to 16.7%) with unfavorable results depending on location. These results suggest that there would be negative effects of Alternative 1 on water temperature conditions for fall-run Chinook salmon in the Sacramento River.

Table O-78. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Adult Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL ADULT MIGRATION RANGE							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (6.7%)	1 (3.3%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	0 (0.0%)	2 (6.7%)	2 (6.7%)
Unfavorable	0 (0.0%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	0 (0.0%)	1 (3.3%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	3 (10.0%)	0 (0.0%)	0 (0.0%)	3 (10.0%)	3 (10.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	1 (3.3%)	4 (13.3%)	4 (13.3%)	4 (13.3%)	4 (13.3%)	6 (20.0%)	5 (16.7%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	0 (0.0%)
Unfavorable	5 (16.7%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	2 (6.7%)	1 (3.3%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Fall-run Chinook Salmon: Summary

Under Alternative 1, differences in seasonal operations in the Sacramento River would result in adverse impacts to adult migration August and September at Keswick Dam, RBDD and Hamilton City, particularly in wet and above normal water years, and in August, September and November at Wilkens Slough. Water temperature analysis suggests there would be adverse impacts of Alternative 1 on water temperature conditions for fall-run Chinook salmon in the Sacramento River.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 259 for Keswick Dam, Table 260 for Red Bluff Diversion Dam, and Table 261 for Hamilton City. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 262 for Keswick Dam, Table 263 for Red Bluff Diversion Dam, and Table 264 for Hamilton City.

Results are summarized in Table O-79. Table O-79, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 37.9°F to 68°F successful adult migration range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-79). There were zero to two combinations (0% to 5.0%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to one combinations (0% to 2.5%) with favorable results and zero to four combinations (0% to 10.0%) with unfavorable results depending on location. These results suggest that there would be negative effects of Alternative 1 on water temperature conditions for late fall-run Chinook salmon adult migration and holding in the Sacramento River.

Combined, results of these analyses suggest that there would be negative effects of Alternative 1 on water temperature conditions for late fall-run Chinook salmon adult migration and holding in the Sacramento River.

Table O-79. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Adult Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL ADULT MIGRATION RANGE							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (5.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	1 (2.5%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	0 (0.0%)	2 (5.0%)	2 (5.0%)
Unfavorable	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	1 (2.5%)	0 (0.0%)	0 (0.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	3 (7.5%)	0 (0.0%)	0 (0.0%)	3 (7.5%)	3 (7.5%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	1 (2.5%)	2 (5.0%)	3 (7.5%)	2 (5.0%)	2 (5.0%)	5 (12.5%)	5 (12.5%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	0 (0.0%)
Unfavorable	4 (10.0%)	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	1 (2.5%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Late Fall-run Chinook Salmon: Summary

Under Alternative 1 relative to the No Action Alternative, differences in seasonal operations in the Sacramento River are largely expected to have similar impacts on late fall-run Chinook salmon adult migration due to changes in flows at Keswick Dam, RBDD, and Hamilton City in October through December. There would be water temperature conditions that are not any more or less favorable than the No Action Alternative with regards to successful adult migration, but there would be a more unfavorable conditions at Hamilton City regarding pathogen virulence for late fall-run Chinook salmon.

O.4.14.2 Clear Creek

Spawning and Egg Incubation

Fall-run Chinook salmon typically spawn in Clear Creek from late September through early December, (Earley et al. 2013). Fall-run Chinook salmon typically emerge from the gravel in December through March. Timing of peak late-fall Chinook salmon spawning in the Sacramento River, January through April, was used as a proxy for Clear Creek. Late fall-run Chinook salmon incubation and emergence is estimated to occur from March through June.

Potential Changes to Fall-run/Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 1, mean spawning WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean spawning WUA under Alternative 1 in comparison to the No Action Alternative. The largest reduction in estimated spawning habitat is an 42% decrease in dry, above normal, and wet water year types. On average across all water year types, there is a 41.8% reduction in estimated spawning habitat under Alternative 1.

The mean values of spawning WUA by month are much lower under Alternative 1 compared to the other alternatives and the No Action Alternative, from October through December (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the four months, December has the highest expected spawning WUA values.

The spawning habitat analysis indicates that Alternative 1 may have a substantial adverse effect, as fall-run Chinook salmon spawning habitat may decrease on average by 41.8% across all water year types in Clear Creek when compared to the No Action Alternative.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 237 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 240 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during December through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 243 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-80. Table O-80, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0% of total combinations during the period) with favorable results and one combination (5.0%) with unfavorable results below Whiskeytown Dam (Table O-80). For the 59.9°F pathogen virulence threshold, there were zero combinations (0%) with favorable results and one combination (5.0%) with unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were no (0%) combinations with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on fall-run Chinook salmon spawning and egg incubation in Clear Creek.

Table O-80. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
42.8°F–56°F RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Fall-run Chinook Salmon: Summary

There may be substantial adverse and moderate beneficial impacts of seasonal operations in Clear Creek on fall-run Chinook salmon spawning and egg incubation based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows may have a substantial adverse impact on spawning habitat (77% decrease on average) across all water year types. Water temperatures outside of the successful spawning range and optimal egg incubation range are expected to have negligible increases in frequency in Clear Creek below Whiskeytown Dam.

Late Fall-run Chinook Salmon: CalSim 3 Flows

Under Alternative 1, average flows below Whiskeytown Dam would be substantially lower than under the No Action Alternative in all months regardless of water year type (Table O-23). During the months of spawning of late fall-run Chinook salmon in Clear Creek (January through April), flows would be reduced by 166 cfs on average which is 68% less than the No Action Alternative. During potential incubation months (January-April) there would also be an average reduction in flow of 166 cfs, with the largest percent decrease of 84% in June. There would be a substantial reduction in spawning habitat available for late fall-run Chinook salmon as a result of flows in Clear Creek.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 269 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 272 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 275 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-81. Table O-81, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 42.1°F to 55°F range for spawning initiation temperature analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results below Whiskeytown Dam (Table O-81). For the 59.9°F pathogen virulence threshold, there were no month-water year type combinations (0%) with favorable or unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were no month-water year type combinations (0%) with favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on late fall-run Chinook salmon spawning and egg incubation in Clear Creek.

Table O-81. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
42.8°F–56°F RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 1 and the No Action Alternative is expected to have substantial impacts on late-fall-run Chinook salmon spawning and egg incubation. Under Alternative 1, changes in flows may have a substantial adverse impact, with decreases in flow among all months and water year types. There would be negligible water temperature-related effects of Alternative 1 on late fall-run Chinook salmon spawning and egg incubation in Clear Creek.

Juvenile Rearing and Emigration

The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, mostly between January through June. Late fall-run Chinook salmon juveniles typically enter the ocean after 7 to 13 months of rearing in freshwater, generally between October and February (Moyle 2002).

Potential Changes To Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under Alternative 1, mean fry rearing WUA increases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The greatest increase in estimated fry rearing habitat between Alternative 1 and the No Action Alternative is a 15.4% increase in above normal water year types. There are no anticipated reductions in mean fry rearing WUA under Alternative 1 in comparison to the No Action Alternative. On average across all water year types, there is a 14% increase in estimated fry rearing habitat under Alternative 1.

The mean values of fry rearing WUA by month are higher under Alternative 1 compared to the No Action Alternative, from January through April (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The expected fry rearing WUA values are similar across all months.

The results of the fall-run fry rearing habitat analysis indicate that Alternative 1 in comparison to the No Action Alternative may have a moderate beneficial effect (14% increase) in estimated fall-run Chinook salmon fry rearing habitat across all water year types in Clear Creek.

Fall-run Chinook Salmon: Juvenile Rearing Habitat Analyses

Under Alternative 1, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 1 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 1 and the No Action Alternative is a 27.6% decrease in critically dry water year types. On average across all water year types, there is a 27.4% reduction in estimated juvenile rearing habitat under Alternative 1.

The mean values of juvenile rearing WUA by month are lower under Alternative 1 compared to the No Action Alternative, from May through September (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The expected juvenile rearing WUA values are similar across all months.

The results of the juvenile rearing habitat analysis indicates that Alternative 1 in comparison to the No Action Alternative may have a moderate to substantial adverse effect (27.4% decrease) in fall-run Chinook salmon juvenile rearing habitat across all water year types.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 250 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 254 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during March through June are presented in Attachment L.1,

Sacramento River Water Temperature Analysis, Table 258 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-82. Table O-82, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-82). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F juvenile pathogen virulence threshold, there were no month-water year type combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Table O-82. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Juvenile Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F JUVENILE PATHOGEN VIRULENCE THRESHOLD							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 1 and the No Action Alternative is expected to have moderate beneficial impacts on fry rearing habitat and substantial impacts on fall-run Chinook salmon juvenile rearing and emigration. Under Alternative 1, changes in flows may decrease on fry and juvenile rearing habitat area with potentially moderate to substantial adverse impacts. Water temperature impacts would be negligible under Alternative 1 on fall-run Chinook salmon juvenile growth, smoltification, predation, and pathogen virulence in Clear Creek below Whiskeytown Dam.

Late Fall-run Chinook Salmon: CalSim 3 Flows

Under Alternative 1, CalSim 3 modeling indicates that average flows below Whiskeytown Dam would be substantially lower than under the No Action Alternative regardless of water year type (Table O-23). During the months of emigration of late fall-run Chinook salmon in Clear Creek (October-February), flows would be reduced by 141 cfs on average which is 62% less than the No Action Alternative during these months. The greatest reduction percentage reduction by month would occur in October with an 74% decrease in flows when compared to the No Action Alternative. There would be a substantial reduction in juvenile and fry rearing habitat available for late fall-run Chinook salmon as a result of flows in Clear Creek.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 282 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 286 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 290 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-83. Table O-83, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-83). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F juvenile pathogen virulence threshold, there were no month-water year type combinations (0%) with favorable results and one combination (1.8%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on late fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Table O-83. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Juvenile Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE RANGE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F JUVENILE PATHOGEN VIRULENCE THRESHOLD							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (1.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 1 and the No Action Alternative is expected to have substantial impacts on late fall-run Chinook salmon juvenile rearing and emigration. Under Alternative 1, substantial decreases in flows will have a substantial adverse impact to late fall-run Chinook salmon juvenile rearing and emigration. There would be similar water temperature-related effects of Alternative 1 on late fall-run Chinook salmon spawning and egg incubation in Clear Creek compared to the No Action Alternative.

Adult Upstream Migration and Holding

Fall-run Chinook salmon may arrive at Clear Creek before spawning from October through early December. Adult late fall-run Chinook salmon migrate and arrive slightly later and do not need to hold and mature before spawning from November into January.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: CalSim 3 Flows

CalSim 3 modeling indicates that average flow released below Whiskeytown Dam under Alternative 1 would be substantially lower than under No Action Alternative regardless of water year type (Table O-23). The largest decrease under Alternative 1 compared to the No Action Alternative occur in February, April through June, and October. The average decrease in flow October through January would be 59% less than the No Action Alternative among all water year types. There would be a substantial reduction in suitable adult migration conditions for adult fall-run Chinook salmon as a result of flows in Clear Creek.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 230 for Clear Creek below Whiskeytown Dam. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 234 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-84. Table O-84, as with all similar temperature analysis results tables in this appendix and as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 37.9°F to 68°F successful adult migration range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results and one combination (3.3%) with unfavorable results below Whiskeytown Dam (Table O-84). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with favorable results and one combination (3.3%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on fall-run Chinook salmon adult upstream migration and holding in Clear Creek.

Table O-84. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Adult Upstream Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL ADULT MIGRATION RANGE							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 1 and the No Action Alternative is expected to have negligible to substantial impacts on adult fall-run Chinook salmon upstream migration. Under Alternative 1, changes in flows would be on average 59% less from October through January resulting in a potentially substantial adverse impact. Water temperature results suggest that there would be negligible impacts of Alternative 1 on fall-run Chinook salmon adult upstream migration and holding in Clear Creek below Whiskeytown Dam, including successful migration and pathogen virulence.

Late Fall-run Chinook Salmon: CalSim 3 Flows

CalSim 3 modeling indicates that average flow released below Whiskeytown Dam under Alternative 1 would generally be significantly lower than under the No Action Alternative regardless of water year type (Table O-23). The largest decrease under Alternative 1 during migration and holding is compared to the No Action Alternative occurs in October. The average decrease in flow October through January would be 59% less than the No Action Alternative among all water year types. There would be a substantial reduction in suitable migration and holding habitat available for adult late fall-run Chinook salmon as a result of flows in Clear Creek.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature above the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 262 for Clear Creek below Whiskeytown Dam. Full results of the percent of months with water temperature outside the 59.9°F adult pathogen virulence threshold analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 266 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-85. Table O-85, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 37.9°F to 68°F successful adult migration range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results and one combination (2.5%) with unfavorable results below Whiskeytown Dam (Table O-85). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with favorable results and one combination (2.5%) with unfavorable results below Whiskeytown. Dam These results suggest that there would be negligible water temperature-related effects of Alternative 1 on late fall-run Chinook salmon adult upstream migration and holding in Clear Creek.

Table O-85. Summary of Results for Water Temperature Analyses for Late Fall-run Chinook Salmon Adult Upstream Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL ADULT MIGRATION RANGE							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F ADULT PATHOGEN VIRULENCE THRESHOLD							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 1 and the No Action Alternative is expected to have substantial impacts on adult fall-run Chinook salmon upstream migration. Under Alternative 1, changes in flows may have a substantial adverse impact, with substantial decreases in flow with an average reduction of 68% January through April. There would be negligible water temperature-related effects of Alternative 1 on late fall-run Chinook salmon adult migration and holding in Clear Creek.

O.4.14.3 Lower American River

Spawning and Egg Incubation

Spawning occurs from about mid-October through early February, with peak spawning from mid-October through December. Chinook salmon spawning occurs within an 18-mile stretch from Paradise Beach to Nimbus Dam; however, most spawning occurs in the uppermost 3 miles (California Department of Fish and Wildlife 2012a). Chinook salmon egg and alevin incubation occurs in the lower American River from about mid-October through April. There is high variability from year to year; however, most incubation occurs from about mid-October through February.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Spawning Habitat—Flow Analysis

Under Alternative 1, fall-run Chinook salmon mean spawning WUA varies modestly among water year types, with no evident trend (Attachment M.3, *American River Weighted Usable Area Analysis*). The highest means are for above normal and critically dry water year types and the lowest is for wet water years. Mean spawning WUA is lower under Alternative 1 than under the No Action Alternative for all water year types, ranging from 4.6% lower for wet water year types to 14.6% lower for above normal water years (Attachment M.3, *American River Weighted Usable Area Analysis*). For all three months of the fall-run Chinook salmon spawning season, estimated spawning WUA under Alternative 1 is lower than that for the No Action Alternative (Attachment M.3, *American River Weighted Usable Area Analysis).* Median WUA for both Alternative 1 and the No Action Alternative is higher in October than November or December because flows, on average, are lower in October (Table O-25). The fall-run Chinook salmon spawning WUA curve (Attachment M.3, *American River Weighted Usable Area Analysis*) peaks at relatively low flows (below 3,000 cfs). It is important to note that the lower American River WUA curve peaks at about 2,000 cfs (Attachment M.3, *American River Weighted Usable Area Analysis*) and flows under Alternative 1 are consistently well above this level in the wetter water years.

Overall, mean spawning WUA is substantially lower under Alternative 1 than under the No Action Alternative.

Redd Dewatering

The results of the analysis for redd dewatering potential for lower American River fall-run Chinook salmon under Alternative 1 indicate that mean redd dewatering potential is greater in wet and above normal water years than in the drier water year types, but the variation among water year types is modest (Attachment M.1, *American River Redd Dewatering Analysis*). The somewhat higher redd dewatering potential in wetter years reflects a greater frequency of large flow fluctuations in those water years. Redd dewatering is consistently higher under Alternative 1 than under the No Action Alternative (Attachment M.1, *American River Redd Dewatering Analysis*). Some of the differences are very large, although the absolute difference in percent redds dewatered between the No Action Alternative and Alternative 1 are much smaller, although they remain substantial (e.g., 9.7% for above normal water years). For the individual months of fall-run Chinook salmon spawning in the lower American River, redd dewatering potential increases from October spawning to that in December, reflecting the somewhat higher flows and likelihood of flow fluctuations over this period (Table O-25).

Overall, mean redd dewatering is much higher under Alternative 1 than under the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 42.1°F to 55°F range for spawning initiation during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 63 for Hazel Avenue and Table 64 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult spawning pathogen virulence threshold during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 65 for Hazel Avenue and Table 66 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence during October through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 67 for Hazel Avenue and Table 68 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during October through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 69 for Hazel Avenue and Table 70 for Watt Avenue.

Results for the 4 analyses are summarized in Table O-86. Table O-86, as described in Section O.4.14.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 42.1°F to 55°F range for spawning initiation under Alternative 1, there were three and one month-water year type combinations (8.6% and 2.9%) with favorable results at both Hazel and Watt Avenue (Table O-86). There were five and two month-water year type combinations (14.3% and 5.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for spawning adults, there were zero month-water year type combinations (0%) with favorable results at both Hazel and Watt Avenue. There were two and zero month-water year type combinations (5.7% and 0.0% respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 42.8°F to 56°F

range for egg incubation and fry emergence analysis, there were four and one month-water year type combinations (13.3% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and four month-water year type combinations (3.3% and 13.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold analysis, there were 0 month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watts Avenue. There were two month-water year type combinations (6.7%) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be positive (2.9%–13.3% favorable) and negative (2.9%–13.3% unfavorable) effects of Alternative 1 on fall-run Chinook salmon spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Table O-86. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Hazel Avenue							
Favorable	3 (8.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (2.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.7%)
Watt Avenue							
Favorable	1 (2.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (5.7%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	1 (2.9%)	1 (2.9%)	0 (0.0%)
59.9°F ADULT SPAWNING PATHOGEN VIRULENCE THRESHOLD							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (5.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (11.4%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	1 (2.9%)	1 (2.9%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	0 (0.0%)
42.8°F–56°F WATER TEMPERATURE RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Hazel Avenue							
Favorable	4 (13.3%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)
Unfavorable	1 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Watt Avenue							
Favorable	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	0 (0.0%)
Unfavorable	4 (13.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	0 (0.0%)	0 (0.0%)	2 (6.7%)
59.9°F FRY PATHOGEN VIRULENCE THRESHOLD							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (10.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	0 (0.0%)
Unfavorable	2 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be moderate to substantial adverse impacts of seasonal operations in the lower American River on fall-run Chinook salmon spawning and egg incubation based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows may have a decrease in WUA and on fry and juvenile rearing habitat area ranging from 4.6% lower for wet water year types to 14.6% lower for above normal water years. Water temperature results are variable and suggest that there could be both beneficial and adverse impacts of Alternative 1 on fall-run Chinook salmon spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue. There would be similar conditions for spawning initiation, pathogen virulence, and a moderate increase in favorable conditions for egg incubation and fry emergence near Hazel Avenue.

Juvenile Rearing and Emigration

Fall-run Chinook salmon fry emergence occurs from January through mid-April, and juvenile rearing extends from January to about mid-July (Williams 2001). Most fall-run Chinook salmon out-migrate from the lower American River as fry from December to July; out-migration peaks in February and March (Snider and Titus 2002; Pacific States Marine Fisheries Commission 2014).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling indicates that the average of all simulated flow releases below Nimbus Dam would be generally highest in June and lowest in September under Alternative 1 compared to the No Action Alternative (Table O-25). The largest increases in flow in June of below normal water year types and April of critically dry year types when compared to the No Action Alternative. The largest flow decreases would occur in September of dry and critically dry water year types when compared to the No Action Alternative. The modeling suggests that flows under Alternative 1 below Nimbus Dam could have a mixed effect. In February under Alternative 1 there is a potential beneficial effect in below normal and dry years with the other water year types having negligible differences, In March flows would be moderately lower in below normal and dry years at 17% and 12% respectively potential minor adverse effect. The greatest difference in flows is an increase of 133% during critically dry years, a significant beneficial effect.

CalSim 3 modeling indicates that the average of all simulated flow releases at H street would be generally highest in June and lowest in September under Alternative 1 compared to the No Action Alternative (Table O-26). The largest increases in flow in June of below normal water year types and April of critically dry year types when compared to the No Action Alternative. The largest flow decreases would occur in September of dry and critically dry water year types when compared to the No Action Alternative. The modeling suggests that flows under Alternative 1 at H Street are expected to have little effect on juvenile rearing and emigration during all water year types except a critically dry year with a mean decrease of 13% in flown between the No Action Alternative and Alternative 1 from February through April, a resulting in a potentially moderate adverse effect.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 71 for Hazel Avenue and Table 72 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F upper incipient lethal temperature (UILT) for juveniles during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 73 for Hazel Avenue and Table 74 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 75 for Hazel Avenue and Table 76 for Watt Avenue.

Results for the three analyses are summarized in Table O-87. Table O-87, as described in Section O.4.14.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability under Alternative 1, there were three and zero month-water year type combinations (12.0% and 0.0%, respectively) with favorable results at both Hazel and Watt Avenue, respectively (Table O-87). There were zero and two month-water year type combinations (0% and 8.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 75.2°F upper incipient lethal temperature (UILT) for juveniles, there were 0 month-water year type combinations (0%) with favorable results at both Hazel and Watt Avenue. There were also zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration, there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and five month-water year type combinations (8.0% and 20.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that Alternative 1 would have positive (4%–12% favorable) and negative (8%–20% unfavorable) water temperature-related effects on fall-run Chinook salmon juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Table O-87. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Hazel Avenue							
Favorable	3 (12.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	3 (12.0%)	1 (4.0%)	2 (8.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)
Unfavorable	2 (8.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (12.0%)	0 (0.0%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
59.9°F PATHOGEN VIRULENCE WATER TEMPERATURE THRESHOLD FOR FALL-RUN CHINOOK SALMON JUVENILE OUTMIGRATION							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Unfavorable	2 (8.0%)	1 (4.0%)	0 (0.0%)	2 (8.0%)	2 (8.0%)	2 (8.0%)	1 (4.0%)
Watt Avenue							
Favorable	1 (4.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	2 (8.0%)	0 (0.0%)
Unfavorable	5 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be both minor adverse impacts and significant beneficial impacts of seasonal operations in the lower American River on fall-run Chinook salmon juvenile rearing and emigration based on analyses of simulated flows depending on water year type. Below Nimbus Dam March flows would be moderately lower in below normal and dry years at 17% and 12% respectively potential minor adverse impact. The greatest difference in flows is a substantial increase of 133% during critically dry years, a significant beneficial impact. Modeled flows at H street suggest that there would be a negligible impact on juvenile rearing and emigration during all water year types except for critically dry years with a moderate decrease in flows under Alternative 1 from February through April, resulting in a potentially moderate adverse impact.

There may be moderate to negligible adverse impact of seasonal operations on fall-run Chinook salmon juvenile rearing in the lower American River based on water temperature results. Results suggest that Alternative 1 would have similar to moderate adverse water temperature-related impacts on fall-run Chinook salmon juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue, with the largest impact being a 20% unfavorable result for pathogen virulence water temperature threshold.

Adult Upstream Migration and Holding

Adult fall-run Chinook salmon enter the lower American River from about mid-September through January, with peak migration from approximately mid-October through December (Williams 2001).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling indicates that the average of all simulated flow releases below Nimbus Dam would be generally highest in June and lowest in September under Alternative 1 compared to the No Action Alternative (Table O-25). The largest increases in flow in June of below normal water year types and April of critically dry year types when compared to the No Action Alternative. The largest flow decreases would occur in September of dry and critically dry water year types when compared to the No Action Alternative. There is a mix of potentially adverse and beneficial impacts to flows during the months of adult fall-run Chinook salmon with the largest decrease being 52% in September of a dry year, the largest increase in flows during adult migration under Alternative 1 is a moderate beneficial increase of 12% in October during the dry water year type.

CalSim 3 modeling indicates that differences in the average of all simulated flow releases at H Street would be generally similar to that below Nimbus Dam under Alternative 1 and therefore has both potentially moderate adverse and beneficial effects to flows during the months of adult fall-run Chinook salmon with the largest decrease being 57% in September of a dry year. Whereas the largest increase in flows during adult migration under Alternative 1 is a moderate beneficial increase of 15% in December during above normal and critically dry years.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 59 for Hazel Avenue and Table 60 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 61 for Hazel Avenue and Table 62 for Watt Avenue.

Results for the two analyses are summarized in Table O-88. Table O-88, as described in Section O.4.14.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 37.9°F to 68°F successful migration range for adult fall-run Chinook salmon under Alternative 1, there were seven and five month-water year type combinations (20% and 8.6%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-88). There were five and seven month-water year type combinations (14.3% and 20.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for adult migration, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were three and zero month-water year type combinations (8.6% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that Alternative 1 would have positive (8.6%–20% favorable) and negative (8.6%–20% unfavorable) water temperature-related effects to fall-run Chinook salmon adult upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue.

Table O-88. Summary of Results for Water Temperature Analyses for Adult Fall-run Chinook Salmon Upstream Migration and Holding for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL MIGRATION RANGE							
Hazel Avenue							
Favorable	7 (20.0%)	3 (8.6%)	3 (8.6%)	3 (8.6%)	4 (11.4%)	6 (17.1%)	4 (11.4%)
Unfavorable	5 (14.3%)	2 (5.7%)	1 (2.9%)	1 (2.9%)	0 (0.0%)	1 (2.9%)	4 (11.4%)
Watt Avenue							
Favorable	3 (8.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.7%)
Unfavorable	7 (20.0%)	3 (8.6%)	4 (11.4%)	2 (5.7%)	3 (8.6%)	7 (20.0%)	2 (5.7%)
59.9°F PATHOGEN VIRULENCE WATER TEMPERATURE THRESHOLD FOR MIGRATION							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	3 (8.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (11.4%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	1 (2.9%)	1 (2.9%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be both moderate adverse and beneficial impacts of seasonal operations in the lower American River on fall-run Chinook salmon adult upstream migration and holding based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, flows would be lower during September in all water year types resulting in a potentially adverse impact while flows would be slightly higher in December during critically dry and above normal water year types resulting in a beneficial impact. Water temperature conditions would result in beneficial and adverse impacts on fall-run Chinook salmon adult migration under Alternative 1. There would be moderate to substantial increases in favorable and unfavorable conditions for growth, smoltification, and predation vulnerability but a minor to moderate increase in unfavorable conditions for pathogen virulence.

O.4.14.4 San Joaquin River

Fall-run Chinook salmon adults migrate upstream through the San Joaquin River past Vernalis between September and November. Juvenile fall-run Chinook salmon migrate downstream past Vernalis primarily January through May. See Section O.1.8.1 for additional information.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

CalSim 3 modeling indicates that the average of all simulated flows in the San Joaquin River at Vernalis would be generally highest in February through May and lowest in August and September under Alternative 1 (Table O-29). Average monthly flows increase compared to the No Action Alternative in all but wet water year types in June through September, and increased for all water year types combined in July through September (6% to 7%. In October, flows decreased relative to the No Action Alternative by -6% to -10% in all but wet water years, with a 6% decrease in flows for all water years combined.

Except in October and November, average monthly flows for all water year types combined would have minor to substantial increases (greater than 5%), but substantial decreases in October, and minor decreases in November except in critically dry water year types, which has a 6% decrease in flow.

Conditions for both upstream and downstream migration are important for September through November and January through May for fall-run Chinook salmon. Migrating adults would experience more substantial decreases in flows in October and November, while migrating juveniles would experience similar to increased beneficial conditions under Alternative 1 compared to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on fall-run Chinook salmon in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

Summary

There may be adverse impacts to migrating adult fall-run Chinook salmon in the San Joaquin River in October through November, but there may be beneficial impacts to migrating juveniles under Alternative 1 compared to the No Action Alternative. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.4.14.5 Bay-Delta

Juvenile Rearing and Emigration

Most fall-run Chinook salmon fry rear in freshwater from December through June, with out-migration as smolts occurring primarily from January through June, with presence in the Delta in December through July. In general, fall-run Chinook salmon fry abundance in the Delta increases following high winter flows. Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. Late fall-run Chinook salmon migrants may be found in the Delta between December and April. See Section O.1.9.1 for additional information.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Differences in hydrology in the Delta under Alternative 1 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using several quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions.

Zone of Influence

Differences in hydrology under Alternative 1 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. These possible differences were evaluated using DSM2-HYDRO outputs. For a detailed description of how flows under Alternative 1 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 1, Sacramento River Winter-run Chinook Salmon ESU (Section O.4.8.2, *Zone of Influence*).

Flow into Junctions

Differences in flow between Alternative 1 and the No Action are expected to influence flow into the Head of Old River and CVP junctions. Under Alternative 1, possibly less flow into CVP under OMR -2,000 and -5,000; possibly less flow into HOR under all OMR groups. Effects of pumping under both Alternative 1 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Summary

Alternative 1 relative to the No Action Alternative is expected to influence flow into the Head of Old River and CVP junctions due to differences in flow. Under Alternative 1, there is expected to be possibly less flow into CVP under OMR -2,000 and -5,000 and; possibly less flow into HOR under all OMR groups. Impacts of pumping under both Alternative 1 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus is more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Fall-run / Late Fall-run Chinook Salmon ESU

Alternative 1 compared with the No Action Alternative may have effects on juvenile fall-run/ late fall-run Chinook salmon entrainment at the Delta Fish Collection Facilities due to differences in exports. These possible differences were evaluated using the Salvage Density model.

Fall-run Chinook Salmon: Salvage Density

Predictions from the salvage density model for fall-run Chinook salmon include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through July and all water year types Alternative 1 was greater than predicted average monthly loss under the No Action Alternative for all water year types.

Predicted average monthly loss at Banks under Alternative 1 had a range from 37% higher for critically dry water year types to 99% higher for below normal water year types (Table O-89). Predicted average monthly loss of fall-run Chinook salmon at CVP Jones Pumping Plant for the months of November through August and all water year types Alternative 1 was greater than predicted average monthly loss under the No Action Alternative. The range of predicted loss for fall-run Chinook salmon at Jones under Alternative 1 compared to the No Action Alternative was from 1% higher in wet water year types to 14% higher for critically dry water year types (Table O-90). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Table O-89. Predicted Average Monthly Loss of Fall-run Chinook Salmon at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	2642	3910 (48%)	3461 (31%)	3457 (31%)	3452 (31%)	3456 (31%)	1561 (-41%)	3402 (29%)	8: Dec–July
Above Normal	1464	2801 (91%)	1995 (36%)	1992 (36%)	1835 (25%)	1815 (24%)	1184 (-19%)	2020 (38%)	8: Dec–July
Below Normal	600	1195 (99%)	1069 (78%)	1089 (81%)	994 (66%)	1007 (68%)	588 (-2%)	1061 (77%)	7: Dec, Feb-July
Dry	653	1246 (91%)	1074 (45%)	1075 (65%)	841 (29%)	825 (26%)	659 (1%)	1070 (64%)	6: Dec, Feb–June
Critically Dry	118	162 (37%)	152 (29%)	143 (21%)	142 (21%)	147 (24%)	131 (11%)	162 (37%)	4: Dec, Mar-May

Table O-90. Predicted Average Monthly Loss of Fall-run Chinook Salmon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	941	950 (1%)	939 (0%)	938 (0%)	934 (-1%)	935 (-1%)	384 (-59%)	943 (0%)	10: Nov–Aug
Above Normal	811	905 (12%)	805 (-1%)	804 (-1%)	786 (-3%)	784 (-3%)	255 (-69%)	809 (0%)	10: Nov–Aug
Below Normal	459	507 (10%)	473 (3%)	456 (-1%)	428 (-7%)	422 (-8%)	123 (-73%)	479 (4%)	7: Jan–July
Dry	528	578 (9%)	522 (-1%)	521 (-1%)	468 (-11%)	466 (-12%)	102 (-81%)	524 (-1%)	7: Dec–June
Critically Dry	75	85 (14%)	79 (5%)	86 (15%)	86 (15%)	86 (14%)	19 (-75%)	77 (2%)	6: Dec–May

Late Fall-run Chinook Salmon: Salvage Density

Predictions from the salvage density model for late fall-run Chinook salmon include mean monthly total exports. Mean monthly total exports at SWP and CVP are greater under Alternative 1 compared with the No Action Alternative for the full simulation period and for the months of January through June. Across the full simulation period combined, and all months of the year, total exports for Alternative 1 ranged from 15% higher (June) to 52% greater (January) compared with the No Action Alternative (Table O-19).

Predicted average monthly loss of late fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through April and all water year types Alternative 1 was greater than predicted average monthly loss under the No Action Alternative for all water year types. Predicted average monthly loss at Banks under Alternative 1 had a range from 40% higher for dry water year types to 95% higher for below normal water year types (Table O-91). Predicted average monthly loss of late fall-run Chinook salmon at CVP Jones Pumping Plant for the months of October through April and all water year types Alternative 1 was greater than predicted average monthly loss under the No Action Alternative. The range of predicted loss for late fall-run Chinook salmon at Jones under Alternative 1 compared to the No Action Alternative was from 6% higher in wet water year types to 21% higher for critically dry water year types (Table O-92). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Table O-91. Predicted Average Monthly Loss of Late Fall-run Chinook Salmon at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	377	617 (64%)	372 (-1%)	372 (-1%)	372 (-1%)	373 (-1%)	222 (-41%)	351 (-7%)	4: Dec–March
Above Normal	300	567 (89%)	293 (-3%)	291 (-3%)	288 (-4%)	287 (-4%)	198 (-34%)	269 (-10%)	4: Dec–March
Below Normal	81	157 (95%)	78 (-3%)	78 (-3%)	77 (-4%)	76 (-5%)	68 (-15%)	78 (-3%)	5: Dec–April
Dry	359	503 (40%)	360 (0%)	358 (0%)	351 (-2%)	340 (-5%)	182 (-49%)	312 (-13%)	2: Dec–Jan
Critically Dry	96	138 (43%)	98 (-5%)	92 (-5%)	88 (-8%)	89 (-8%)	76 (-21%)	95 (-1%)	5: Dec–April

Table O-92. Predicted Average Monthly Loss of Late Fall-run Chinook Salmon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	58	61 (6%)	57 (-1%)	57 (-1%)	57 (-1%)	58 (-1%)	43 (-25%)	55 (-5%)	5: Oct–Feb
Above Normal	49	58 (18%)	52 (6%)	52 (6%)	52 (7%)	52 (7%)	26 (-47%)	50 (2%)	5: Oct–Feb
Below Normal	14	17 (17%)	14 (-3%)	14 (-3%)	14 (-4%)	14 (-4%)	7 (-53%)	14 (-2%)	5: Dec–April
Dry	42	48 (14%)	43 (3%)	42 (0%)	41 (-1%)	41 (-1%)	18 (-58%)	42 (-1%)	2: Dec–Jan
Critically Dry	29	35 (21%)	27 (-5%)	29 (1%)	30 (4%)	30 (4%)	15 (-47%)	29 (2%)	4: Dec–March

Summary

Alternative 1 relative to the No Action Alternative is expected to have substantial adverse impact on the entrainment of the juvenile fall-run and late fall-run Chinook salmon in the Delta at both fish facilities due to differences in flow, supported by results from the salvage density quantitative model.

Potential changes to through Delta survival of fall-run / late fall-run Chinook salmon ESU

Delta Passage Model

The DPM simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River and estimates survival to Chipps Island. For this application, only survival of fish entering the Delta from the Sacramento River are evaluated.

- **Fall-run Chinook Salmon:** Under Alternative 1, in below normal and critically dry water year types, predicted mean survival of fall-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted proportion surviving to Chipps Island in all water year types is less than ± 0.001. There is not a substantial difference in predicted proportion of fall-run Chinook salmon surviving to Chipps Island between Alternative 1 and the No Action Alternative.
- **Late Fall-run Chinook Salmon:** Under Alternative 1, in all water year types, predicted mean survival of late-fall-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted survival to Chipps Island in all water year types less than or equal to ± 0.008. There is not a substantial difference in predicted proportion of late-fall-run Chinook salmon surviving to Chipps Island between Alternative 1 and the No Action Alternative.

Summary

Under Alternative 1 compared to the No Action Alternative, there would be negligible impacts to through Delta survival for both fall-run and late fall-run Chinook salmon through the Delta to Chipps Island.

O.4.14.6 Stanislaus River

Spawning and Egg Incubation

Peak spawning for fall-run Chinook salmon in the Stanislaus River typically occurs in November with roughly 7% of spawning occurring prior to November 1, and 2% prior to October 15. The few redds created during late September and early October are typically in the reach just below Goodwin Dam with spawning typically ending in December.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Spawning Habitat—Flow Analysis

The results for Alternative 1 show similar mean spawning WUA in critically dry to above normal water year types, but much lower spawning WUA in wet years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the shape of the fall-run spawning WUA curves (which show reduced WUA with increased flow, except at the lowest and highest flows (less than about 200 cfs to 500 cfs and greater than about 1,000 cfs, respectively). CalSim 3 mean monthly flows below Goodwin Dam, which is immediately upstream of the WUA study reach, are 200 cfs or above in all water year types, with flow generally increasing from critically dry to wet water years during all months of the October through December fall-run spawning period (Table O-27). The mean spawning WUA estimates for Alternative 1 are similar or much higher than those for the No Action Alternative in all water year types, ranging from 0.6% lower in critically dry water years to 18.7% higher in above normal water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fall-run Chinook salmon spawning period, median spawning WUA is lower in October than in November or December despite lower mean flows in October (Table O-27). However, October mean flows in the drier water years under Alternative 1 fall well to the left of the peaks of the spawning WUA curves (200 cfs to 500 cfs) while those in November and December sit closer to the peaks of the curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The median WUA in October for Alternative 1 is much higher than that for the No Action Alternative because October mean flows under the No Action Alternative lie well to the right of the spawning WUA peaks (Table O-27).

Overall, the results indicate that mean spawning WUA for fall-run Chinook salmon in the Stanislaus River is higher under Alternative 1 than under the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 55 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult spawning pathogen virulence threshold during October through January are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 56 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 57 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 58 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-93. Table O-93, as described in Section O.4.14.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 42.1°F to 55°F range for spawning initiation there were zero month-water year type combinations (0.0%) with favorable results and four month-water year type combinations (20.0%) with unfavorable results at Orange Blossom Bridge (Table O-93). For the 59.9°F adult spawning pathogen virulence threshold there were zero month-water year type combinations (0%) with favorable results and four combinations (15.0%) with unfavorable results at Orange Blossom Bridge. For the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 59.9°F fry pathogen virulence threshold there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge. These results suggest that Alternative 1 would have negative water temperature-related effects on fall-run Chinook salmon spawning and egg incubation.

Table O-93. Summary of Results for Water Temperature Analyses for fall-run Chinook salmon spawning and egg incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
42.1°F–55°F RANGE FOR SPAWNING INITIATION							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	4 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)
59.9°F ADULT SPAWNING PATHOGEN VIRULENCE THRESHOLD							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	3 (15.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
42.8°F–56°F WATER TEMPERATURE RANGE FOR EGG INCUBATION AND FRY EMERGENCE							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F FRY PATHOGEN VIRULENCE THRESHOLD							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Under Alternative 1 compared to the No Action Alternative, there are expected adverse to beneficial impacts of seasonal operations in the Stanislaus River on fall-run Chinook salmon spawning and egg incubation. Alternative 1 relative to the No Action Alternative is expected to have minor to moderate beneficial impacts on spawning habitat area.. The water temperature model results at these locations suggest that Alternative 1 would have frequent adverse water temperature-related impacts on fall-run Chinook salmon spawning and egg incubation. There would be a moderate increase in unfavorable conditions affecting spawning initiation, but similar conditions for egg incubation and fry emergence and pathogen virulence.

Juvenile Rearing and Emigration

Fall-run juvenile rearing in the Stanislaus River typically occurs from January through May (Stanislaus River Fish Group 2004). Fry migration generally occurs from January through March, followed by smolt migration from April through May (Bureau of Reclamation 2012).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Rearing Habitat—WUA Flow Analyses

The results for fall-run fry rearing WUA under Alternative 1 generally show only minor differences in mean WUA among water year types, with WUA generally increasing from wetter to drier water year types, except for a sharp reduction from dry to critically dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the fall-run fry WUA curves, which show reduced WUA with increased flow, especially in the Orange Blossom Bridge and Riverbank reaches (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which are the longest segments of the study. Mean fry rearing WUA under Alternative 1 is similar to that for the No Action Alternative in all water year types, ranging from 5.2% lower in critically dry water years to 5.4% higher in wet water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fry rearing period, fry rearing is higher under Alternative 1 than under the No Action Alternative in March and lower in February, April and May, but none of the differences is large (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results for juvenile rearing WUA under Alternative 1 show only minor changes in mean rearing WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Juvenile mean rearing WUA is higher under Alternative 1 than under the No Action Alternative, but most differences are small, ranging from 1.0% higher for above normal water years to 6.4% higher for dry water years. Juveniles fall-run rear from March to October. Median juvenile rearing WUA is highest in April and May (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The median WUA under Alternative 1 relative to the No Action Alternative is much higher in March, much lower in October, moderately lower in April and May, and moderately higher in the remaining months.

Overall, the results indicate that fry and juvenile rearing WUA in the Stanislaus River for fall-run Chinook salmon are largely similar under Alternative 1 to those under No Action Alternative.

Rearing Habitat—ASH Flow Analyses

The results of the Area of Suitable Habitat (ASH) analysis for fall-run Chinook salmon fry and juvenile rearing are quite different from the rearing WUA results described above with respect to how mean ASH varies with water year type. The mean ASH estimates consistently increase from critically dry to wet years. This pattern of variation reflects the overall relationship between flow and ASH for both life stages determined from modeling and field studies (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in fry and juvenile ASH between Alternative 1 and the No Action Alternative are more variable than those found for the rearing WUA results. Fry rearing ASH for dry water years is 12.9% higher under Alternative 1 than the No Action Alternative. The differences for the other water year types are less than 3%. Mean juvenile rearing ASH under Alternative 1 is 23.7% and 14.9% higher for dry and critically dry

water year types, respectively, relative the No Action Alternative, while differences for the other water year types are less than 3% (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that fry and juvenile rearing ASH in the Stanislaus River for fall-run Chinook salmon under Alternative 1 are similar to or are higher than those under No Action Alternative, depending on water year type.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 59 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F upper incipient lethal temperature (UILT) for juveniles during March through June are presented in Attachment *N*.1, *Stanislaus River Water Temperature Analysis*, Table 60 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 61 for Orange Blossom Bridge.

Results for the three analyses are summarized in Table O-94. Table O-94, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.14.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability there were two month-water year type combinations (10.0%) with favorable results and 5 month-water year type combinations (25.0%) with unfavorable results at Orange Blossom Bridge (Table O-94). For the 75.2°F upper incipient lethal temperature (UILT) for juvenile fall-run Chinook salmon there were no month-water year type combinations (0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration there was one month-water year type combination (5%) with favorable results and one combination with unfavorable results at Orange Blossom Bridge. These results suggest that there would be positive and negative water temperature-related effects of Alternative 1 on fall-run Chinook salmon juvenile rearing and emigration.

Table O-94. Summary of Results for Water Temperature Analyses for Fall-run Chinook Salmon Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
55.4°F–68°F OPTIMUM TEMPERATURE FOR JUVENILE GROWTH, SMOLTIFICATION, AND PREDATION VULNERABILITY							
Orange Blossom Bridge							
Favorable	2 (10.0%)	2 (10.0%)	2 (10.0%)	2 (10.0%)	2 (10.0%)	0 (0.0%)	2 (10.0%)
Unfavorable	5 (25.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (15.0%)	0 (0.0%)
75.2°F UPPER INCIPIENT LETHAL TEMPERATURE (UILT) FOR JUVENILES							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59.9°F PATHOGEN VIRULENCE WATER TEMPERATURE THRESHOLD FOR FALL-RUN CHINOOK SALMON JUVENILE OUTMIGRATION							
Orange Blossom Bridge							
Favorable	1 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)
Unfavorable	1 (5.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	0 (0.0%)	1 (5.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Under Alternative 1, there are expected adverse and beneficial impacts of seasonal operations in the Stanislaus River on fall-run Chinook salmon juvenile rearing and emigration based on analyses of simulated flows, depending on month and water year type. The results of the WUA analysis indicate that fry and juvenile rearing habitat are largely similar under Alternative 1 to those under No Action Alternative. The results of the ASH analysis indicate that fry and juvenile rearing habitat under Alternative 1 are similar to or are higher than those under No Action Alternative, depending on water year type. Water temperature modeling results suggest that there would also be potential beneficial and adverse water temperature-related impacts of Alternative 1 on fall-run Chinook salmon juvenile rearing and emigration. There would be a occasional increases in favorable conditions but frequent increases in unfavorable conditions affecting growth, smoltification and predation vulnerability, but minor impacts to pathogen virulence.

Adult Upstream Migration and Holding

Fall-run Chinook salmon adults generally migrate upstream from late September through December with peak migration from late October through early November in the Stanislaus River.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling indicates that average flow released below Goodwin Dam under Alternative 1 compared to No Action Alternative would generally be higher November, December, February, and June in most water year types (Table O-27). The largest decreases under Alternative 1 compared to the No Action Alternative occur in October of all water year types. Under Alternative 1 flows at the mouth of the Stanislaus River would generally be higher from February through September, and generally lower from October through November (Table O-28).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during July through December are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 51 for Orange Blossom Bridge and Table 52 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration during July through December are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 53 for Orange Blossom Bridge and 54 for above the confluence with the San Joaquin River.

Results for the two analyses are summarized in Table O-95. Table O-95, as described in Section O.4.14.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 37.9°F to 68°F successful migration range for adult fall-run Chinook salmon there were no month-water year type combinations (0.0%) with favorable or unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-95). For the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration there were one and zero month-water year type combinations (3.3% and 0.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence of the San Joaquin River, respectively. There were four month-water year type combinations (13.3%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. These results suggest that Alternative 1 would have negative water temperature-related effects on fall-run Chinook salmon upstream holding and migration in the Stanislaus River at Orange Blossom Bridge and above the confluence of the San Joaquin River.

Table O-95. Summary of Results for Water Temperature Analyses for Adult Fall-run Chinook Salmon Upstream Migration and Holding for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
37.9°F–68°F SUCCESSFUL MIGRATION RANGE							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above Confluence							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (6.7%)	0 (0.0%)
59.9°F PATHOGEN VIRULENCE WATER TEMPERATURE THRESHOLD FOR MIGRATION							
Orange Blossom Bridge							
Favorable	1 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	4 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (10.0%)	0 (0.0%)
Above Confluence							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	4 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (6.7%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be both adverse impacts and significant beneficial impacts of seasonal operations in the Stanislaus River on fall-run Chinook salmon upstream migration and holding based on analyses of simulated flows. Below Goodwin Dam, flows would be significantly lower in all water year types during the month of October. Alternatively, flows would increase an average of 35% in all water types during the month of November, a significant beneficial impact, except during a critically dry year this benefit would be minimal with a 7% increase in flow. Subsequently under Alternative 1 flows at the mouth of the Stanislaus would also be significantly lower in all water year types during the month of October. The water temperature model results suggest that for adult fall-run Chinook salmon there were no month-water year type combinations (0.0%) with favorable or unfavorable results for successful migration at both Orange Blossom Bridge and above the confluence of the San Joaquin River. There is a potential to have adverse water temperature-related impact on fall-run Chinook salmon pathogen with 13.3% unfavorable at both Orange Blossom Bridge and above the confluence. There would be

minor changes to successful migration, but a moderate increase in unfavorable conditions for pathogen virulence.

O.4.15 White Sturgeon

O.4.15.1 Sacramento River

Spawning and Egg Incubation

White sturgeon spawning occurs in deep water in the middle and lower Sacramento River from near Verona (~RM 80) to just upstream of Colusa (~RM 156) from late February to early June, peaking during March and April, (Section O.1.3.2.6, *White Sturgeon*). Because the incubation time for white sturgeon is so short (4-12 days depending on water temperature; Wang 1986), the peak analysis period for incubating eggs is also considered to be March and April.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the March and April spawning and egg incubation period of white sturgeon, CalSim 3 estimates of mean monthly flows at Wilkins Slough (RM 117) under Alternative 1 range from about 4,600 cfs for April of critically dry water years to about 18,000 cfs for March of wet water years (Table O-16). Because white sturgeon spawn in deep pools, these flow levels are likely to be adequate for spawning and egg incubation, so no adverse effects are expected to result. Differences in flows between Alternative 1 and the No Action Alternative are small in both months, but flows are moderately higher (16%) for Alternative 1 in April of critically dry water years (Table O-16). Therefore, Alternative 1 would likely have minimal beneficial flow effects on white sturgeon eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 61°F upper limit for optimal egg incubation during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 291 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 68°F upper limit for embryo hatching during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 292 for Hamilton City.

Results for the two analyses are summarized in Table O-96. Table O-96, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 61°F upper limit for optimal egg incubation, there were two month-water year type combinations (10.0% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable results at Hamilton City (Table O-96). For the 68°F upper limit for embryo hatching, there were no combinations (0%) with favorable or unfavorable results at Hamilton City. These results suggest that there would be positive water temperature-related effects of Alternative 1 on white sturgeon spawning and egg incubation in the Sacramento River.

Table O-96. Summary of Results for Water Temperature Analyses for White Sturgeon Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
61°F UPPER LIMIT FOR OPTIMAL EGG INCUBATION							
Hamilton City							
Favorable	2 (10.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)	3 (15.0%)	0 (0.0%)
68°F UPPER LIMIT FOR EMBRYO HATCHING							
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have possible beneficial impacts on spawning habitats due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have possible beneficial impacts on spawning and egg incubation depending on location, month, and water year type due to differences in water temperature.

Larval and Juvenile Rearing and Emigration

The white sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch (Heublein et al. 2017a, Deng et.al 2002). Therefore, since white sturgeon spawn from late February to early June, peaking in March and April, the larval period is considered to be March through June. Juvenile white sturgeon are believed to initiate a secondary dispersal (the primary dispersal occurring at the larval stage) in spring by actively swimming downstream during the night (Heublein et al. 2017a). The juvenile emigration period is considered to be April through July. Therefore, the effects analysis period for larvae and juvenile rearing and emigration is considered to be March through July.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the white sturgeon larval and juvenile rearing and emigration period, approximately April to July, CalSim 3 estimates of mean monthly flows at Wilkins Slough under Alternative 1 range from about 3,600 cfs for May of critically dry water years to about 14,100 cfs for April of wet

water years (Table O-16). CalSim 3 results indicate that flows during April through July would generally increase (up to 23%) with Alternative 1 compared to the No Action Alternative. However, under Alternative 1 compared to the No Action Alternative, flows would decrease in July of above normal and below normal years (7%) (Table O-16). Alternative 1 may have a minimal beneficial effect on larval and juvenile white sturgeon relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66°F limit above which stress is observed in juvenile white sturgeon year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 293 for Hamilton City.

Results for the analysis are summarized in Table O-97. Table O-97, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 66.6°F stress limit for juvenile white sturgeon, there were four month-water year type combinations (6.7% of total combinations during the period, respectively) with favorable results and no combinations (0%) with unfavorable results at Hamilton City (Table O-97). These results suggest that there would be negligible positive water temperature-related effects of Alternative 1 on white sturgeon larval and juvenile rearing and emigration in the Sacramento River.

Table O-97. Summary of Results for Water Temperature Analyses for White Sturgeon Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
66°F LIMIT ABOVE WHICH STRESS IS OBSERVED IN JUVENILE WHITE STURGEON							
Hamilton City							
Favorable	4 (6.7%)	3 (5.0%)	4 (6.7%)	3 (5.0%)	3 (5.0%)	4 (6.7%)	3 (5.0%)
Unfavorable	0 (0.0%)	1 (1.7%)	0 (0.0%)	1 (1.7%)	1 (1.7%)	2 (3.3%)	1 (1.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have possible beneficial impacts on rearing and emigration habitats due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have minor beneficial impacts on rearing and emigration depending on location, month, and water year type due to differences in water temperature.

Adult Upstream Migration and Holding

Adult white sturgeon ready for spawning likely move into the lower reaches of the Sacramento River during early winter to begin their upstream migration (Section O.1.3.2.6, *White Sturgeon*). Upstream migration appears to be rapid, with minimal holding time (Schaffter 1997, Heublein et al. 2017a). Based on rapid upstream migration, short egg incubation period, and larval presence in the Sacramento River; the adult upstream migration and holding period is considered to be December to February for this effects analysis.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the white sturgeon adult upstream migration and holding period, approximately December to February, CalSim 3 estimates of mean monthly flows at Wilkins Slough under Alternative 1 range from about 6,300 cfs for January of critically dry water years to about 19,900 cfs for February of wet water years (Table O-16). CalSim 3 results indicate that flows during December through February would generally remain similar (up to 2%) with Alternative 1 compared to the No Action Alternative, with the exception of increased flows in December of above normal water years (7%) (Table O-16). Alternative 1 would have a similar effect on upmigrating and holding adult white sturgeon relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperature for adult white sturgeon during November through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 294 for Hamilton City.

Results for the analysis are summarized in Table O-98. Table O-98, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 77°F upper limit of suitable water temperature for adult white sturgeon, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results (Table O-98). These results suggest that there would be negligible water temperature-related effects of Alternative 1 on adult white sturgeon migration and holding in the Sacramento River.

Table O-98. Summary of Results for Water Temperature Analyses for White Sturgeon Adult Migration and Holding in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
77°F UPPER LIMIT OF SUITABLE WATER TEMPERATURE FOR ADULTS							
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on upstream migration and holding habitats due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on upstream migration and holding depending on location, month, and water year type due to differences in water temperature.

O.4.15.2 Lower American River

Limited quantitative information is available on the distribution and status of white sturgeon in the lower American River; however, small numbers of adults apparently use the lower American River, as evidenced by sturgeon report cards submitted to the CDFW by anglers in recent years (Section O.1.6.2.1, *Fish Evaluated in the Lower American River*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Adult white sturgeon have been reported by anglers in the lower American River during all months of the year, peaking in March-April and November-December (California Department of Fish and Wildlife 2023i). During all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 1 range from about 551 cfs for September of critically dry water years to about 12,306 cfs for February of wet water years (Table O-25). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 1 compared to the No Action Alternative, with a few exceptions. Flows under Alternative 1 for all water years would decrease in July, September, and November (up to 20%) and increase in April and June (up to 16%) (Table O-25).

During all months, CalSim 3 estimates of mean monthly flows at H Street under Alternative 1 range from about 689 cfs for September of critically dry water years to about 12,283 cfs for February of wet water years (Table O-26). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 1 compared to the No Action Alternative, with a few exceptions. Flows under Alternative 1 for all water years would decrease in July, August, and September, and November (up to 22%) and increase in April and June (up to 17%) (Table O-26).

White sturgeon are not likely to be affected by changes in flow under Alternative 1 compared to the No Action Alternative due to their limited distribution in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperatures for adult white sturgeon year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 77 for Hazel Avenue and Table 78 for Watt Avenue.

Results for the analysis are summarized in Table O-99. Table O-99, as described in Section O.4.15.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 77°F upper limit of suitable water temperatures for adult white sturgeon under Alternative 1, there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-99). There were also zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. These results suggest that Alternative 1 would have negligible water temperature-related effects to non-spawning white sturgeon in the lower American River at Hazel Avenue and Watt Avenue.

Table O-99. Summary of Results for Water Temperature Analyses for Non-spawning Adult White Sturgeon for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
77°F UPPER LIMIT OF SUITABLE WATER TEMPERATURES							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on white sturgeon habitat due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on white sturgeon across all locations, months, and water year types.

O.4.15.3 San Joaquin River

Little is known about white sturgeon populations inhabiting the San Joaquin River. White sturgeon spawning in the San Joaquin River was documented for the first time in 2011 and confirmed in 2012. Although the majority of sturgeon likely spawn in the Sacramento River, the results of these surveys confirm that white sturgeon do spawn in the San Joaquin River in both wet- and dry-year conditions and may be an important source of production for the white sturgeon population in the Sacramento–San Joaquin River system (Section O.1.8.2.4, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

Using the Sacramento River as a surrogate, it can be inferred that the spawning period for white sturgeon in the San Joaquin River also occurs in deep water from late February to early June, peaking during March and April, (Section O.1.8.2.4, *White Sturgeon*). Because the incubation time for white sturgeon is so short, the peak impacts analysis period for incubating eggs is also considered to be March and April. Since confirmed spawning events took place in the San Joaquin River, it is reasonable to assume that rearing larvae, emigrating juveniles, and migrating adults are also present in the San Joaquin River, but due to the lack of information on these life stages they are not part of this analysis.

During the evaluated months in the spawning period, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 1 range from about 2,159 cfs for March of critically dry water years to about 12,545 cfs for April of wet water years (Table O-29). CalSim 3 results indicate that differences in flows during March and April would generally be minimal (up to 4%) under Alternative 1 compared to the No Action Alternative, with a couple exceptions. Flows under Alternative 1 would increase in March of critically dry years (6%) and in April of dry years (9%) (Table O-29). Due to spawning occurring in deep pools, it is not anticipated that flows under Alternative 1 would have an effect on white sturgeon spawning compared to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on white sturgeon in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on spawning habitat due to differences in flow. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.4.15.4 Bay-Delta

Juvenile Rearing and Emigration

White sturgeon are believed to be most abundant within the Bay-Delta region. Juveniles can be found throughout the Delta year-round. Additionally, white sturgeon larvae have been observed to be flushed farther downstream into the Delta and Suisun Bay in high outflow years, but otherwise rear higher in the system (Section O.1.9.1.6, *White Sturgeon*). Due to limited data on larval presence in the Bay Delta, only the juvenile life stage is evaluated in this analysis.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During all months, CalSim 3 estimates of mean monthly flows in the Sacramento River at Rio Vista under Alternative 1 range from about 3,423 cfs for August of critically dry water years to about 104,496 cfs for February of wet water years (Table O-22). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 1 compared to the No Action Alternative, with a few exceptions. Flows under Alternative 1 for wet water years would moderately decrease in July through October (up to 19%) and moderately increase in June (11%). Flows in above normal water years would moderately decrease in July through November (up to 17%) and moderately increase in June (24%). Flows in below normal water years would moderately decrease in July, August, and November (up to 11%) and moderately increase in February, June, and September (up to 25%). Flows in dry water years would moderately decrease in January and September (up to 10%). Flows in critically dry water years would moderately decrease in January and December (up to 10%), moderately increase in May through July (up to 26%), and substantially increase in April (49%) (Table O-22).

CalSim 3 estimates of mean monthly average total exports from SWP and CVP under Alternative 1 range from 1,556 cfs for August of critically dry water years to about 12,805 cfs for January of wet water years (Table O-19). For all water year types, CalSim 3 results indicate that differences in exports during January through December would substantially increase (up to 76%) under Alternative 1 compared to the No Action Alternative with a few exceptions. Exports would moderately decrease in August of below normal water years, September of dry water years, and November of wet and above normal water years (up to 16%) (Table O-19). It is not anticipated that exports under Alternative 1 would have an effect on white sturgeon juveniles compared to the No Action Alternative and may have a positive effect on juveniles during critically dry years.

Delta Outflow vs Sturgeon YCI

Differences in year class strength between Alternative 1 and the No Action Alternative are expected to be negligible. For additional effects of spring Delta outflow vs white sturgeon YCI

under Alternative 1, refer to the analysis in Section O.4.11.3.1, *[Green Sturgeon] Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts to possible beneficial impacts on juvenile white sturgeon year class strength due to differences in flow.

Potential Changes to Entrainment of White Sturgeon

Salvage Density

Predictions from the salvage density model (Attachment I.2, *Salvage Density Model Loss Simulation*) for white sturgeon include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of white sturgeon of Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were greater than the majority of months of wet and above normal water year types, and less than half of the months in dry water year types; however, no loss is anticipated in critically dry year types at either facility. At the SWP Banks Pumping Plant predicted average monthly loss was up to 99% greater for January and May of dry water year types and as low as 34% of below normal water year types (Table O-100 and Table O-101). At CVP Jones Pumping Plant predicted average monthly loss was up to 11% greater for January and May of dry water year types and decreased up to 8% on dry water year types (Table O-101). Historical loss of white sturgeon at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Table O-100. Predicted Average Monthly Loss of White Sturgeon at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	2	3 (35%)	3 (7%)	3 (7%)	3 (6%)	3 (6%)	1 (-47%)	3 (5%)	8: Dec–March, May–Aug
Above Normal	2	3 (60%)	2 (4%)	2 (4%)	2 (1%)	2 (1%)	1 (-39%)	2 (3%)	8: Dec–March, May–Aug
Below Normal	2	3 (34%)	2 (-2%)	2 (-1%)	2 (-4%)	2 (-5%)	2 (-31%)	2 (-9%)	5: March–April, June, Nov–Dec
Dry	2	4 (99%)	2 (25%)	2 (25%)	2 (16%)	2 (12%)	2 (-4%)	2 (32%)	2: Jan, May
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Table O-101. Predicted Average Monthly Loss of White Sturgeon at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	11	11 (-2%)	11 (-4%)	11 (-4%)	11 (-4%)	11 (-4%)	4 (-61%)	11 (-4%)	7: May–Nov
Above Normal	10	11 (10%)	10 (-2%)	10 (-2%)	10 (-4%)	10 (-4%)	2 (-80%)	10 (-2%)	7: May–Nov
Below Normal	5	5 (11%)	5 (-1%)	4 (-3%)	4 (-3%)	4 (-3%)	2 (-49%)	5 (0%)	4: Feb, May, Oct, Dec
Dry	1	1 (-8%)	1 (1%)	1 (1%)	1 (0%)	1 (2%)	1 (-35%)	1 (1%)	1: Nov
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor impacts on the entrainment of juvenile white sturgeon at both facilities due to differences in flow. Modeled results from the quantitative model show possible beneficial and adverse impacts, but since white sturgeon are salvaged so rarely, the numbers may not be representative.

Subadult and Adult Residency

White sturgeon are believed to be most abundant within the Bay-Delta region. Non-spawning adults can be found throughout the Delta year-round. When not undergoing spawning or ocean migrations, adults and subadults are usually most abundant in brackish portions of the Bay-Delta (Section O.1.9.1.6, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Similar to juveniles, subadults and non-spawning adults are in the Bay-Delta year-round. Refer to the *CalSim 3 Flows* section above under *Juvenile Rearing and Emigration* for changes in flow under Alternative 1 compared to the No Action Alternative.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts to possible beneficial impacts on white sturgeon year class strength due to differences in flow.

O.4.16 Native Minnows

O.4.16.1 Sacramento River

Sacramento Splittail, Hardhead, and Sacramento Hitch

- **Sacramento Splittail:** Historically, Sacramento splittail was widespread in the Sacramento River from Redding to the Delta (Rutter 1908, as cited in Moyle et al. 2004). This distribution has become somewhat reduced in recent years (Sommer et al. 1997, 2007b). During drier years there is evidence that spawning occurs farther upstream (Feyrer et al. 2005). Adult splittail migrate upstream in the lower Sacramento River to above the mouth of the Feather River and into the Sutter and Yolo Bypasses (Sommer et al. 1997; Feyrer et al. 2005; Sommer et al. 2007b). Each year, mainly during the spring spawning season, a small number of individuals have been documented at the Red Bluff Pumping Plant and the entrance to the GCID intake (Moyle et al. 2004).

  Most juvenile Sacramento splittail move from upstream areas downstream into the Delta from April through August (Meng and Moyle 1995; Sommer et al. 2007b). The production and recruitment of YOY Sacramento splittail is largely influenced by extent and duration of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Sommer et al. 1997; Moyle et al. 2004; Feyrer et al. 2006).

- **Hardhead:** Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986). They migrate upstream and into tributary streams as far as 45 miles (72.4 km) to spawning sites. Spawning behavior has not been documented, but it is assumed to be similar to that of the pikeminnow, which deposit their eggs over gravel-bottomed riffles, runs, and at the head of pools (Moyle et al. 1995). Hardhead larvae and juveniles likely inhabit stream margins with abundant cover and move into deeper habitats as they grow larger. Juvenile and adult hardhead are present in the Sacramento River year-round.

- **Sacramento Hitch:** Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta (Moyle et al. 2015). Sacramento hitch were not known to occur in high abundance in the Sacramento watershed, but they are known to prefer shallow backwater areas and historically were observed in the upper and lower Sacramento River and north Delta (Brown & May, 2006; Robinson & Safran, 2014).

  Moyle et al. (2015) summarized habitat and distribution: Spawning takes place mainly in riffles of streams tributary to lakes, river, and sloughs after flows increase in response to spring rains, but spawning requirements are in need of further documentation. Moyle et al. (2015) indicate that YOY hitch spend the next two months after hatching shoaling in shallow water or staying close to aquatic plants before moving out into more open water at around 50-mm fork length.

Potential Changes to Sacramento Splittail, Hardhead, and Sacramento Hitch from Seasonal Operations

CalSim 3 Flows

The greatest factor in determining native minnow spawning success and recruitment is the amount and duration that crucial floodplain spawning areas are inundated during the period of native minnow migration and spawning. In wet years flows over 22,500 cfs at Tisdale, the first flood control gate, would cause the Tisdale weir to begin spilling into the Sutter Bypass (DWR 2010b). Adult migration generally occurs during the late winter with juvenile outmigration into the Delta occurring in spring/early summer. Exact migration, spawning and outmigration timing are not well understood for native minnows, so flows were examined for the months of December through May.

CalSim 3 modeling indicates that average flow released at Keswick Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative from December through May, except in critically dry water years in February, when the Alternative 1 flows would be lower (Table O-14). Native minnows need adequate flows to allow access to upstream spawning/rearing habitat. There is likely negligible flow effects on native minnows since flow differences were minimal under Alternative 1 compared to the No Action Alternative.

CalSim 3 estimates of mean monthly flows for the Sacramento River at Wilkins Slough under Alternative 1 range from about 3,600 cfs for May of critically dry water years to about 14,100 cfs for April of wet water years (Table O-16). For the full simulation period the difference in CalSim 3 flow estimates under Alternative 1 compared to the No Action Alternative at Wilkins are minimal, with only a 2% increase in flows for December and May (Table O-16). Under Alternative 1, CalSim 3 flow estimates at Wilkins would have a negligible effect on native minnow spawning and migration as compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 75°F observed range of suitable water temperatures for Sacramento splittail during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 307 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 84.2°F range of preferred temperatures in lab and field observations for Sacramento hitch non-spawning adults year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 308 for Keswick Dam, 309 for Red Bluff Diversion Dam, and 310 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 64°F optimal water temperature range for hardhead spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 311 for Keswick Dam and 312 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature outside the 57.2°F to 78.8°F commonly observed range of temperatures for non-spawning adult hardhead year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 314 for Keswick Dam and 315 for Red Bluff Diversion Dam.

Results for the four analyses are summarized in Table O-102. Table O-102, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 45°F to 75°F observed range for suitable Sacramento splittail spawning, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Hamilton City (Table O-102). For the 77-84.2°F preferred range for non-spawning Sacramento hitch, there were no combinations (0%) with favorable or unfavorable results at any location analyzed. For the 59-64°F optimal hardhead spawning range, there were no combinations (0%) with favorable results at both locations analyzed. There were zero and nine combinations (0% and 60.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead. There were zero and 10 combinations (0% and 16.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were zero and five combinations (0% and 8.3%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 1 on native minnows in the Sacramento River.

Table O-102. Summary of Results for Water Temperature Analyses for Native Minnow Spawning and Non-spawning Adults in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
45-75°F OBSERVED SACRAMENTO SPLITTAIL SPAWNING RANGE							
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
77-84.2°F PREFERRED RANGE FOR NON-SPAWNING SACRAMENTO HITCH IN LAB AND FIELD OBSERVATIONS							
Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59-64°F OPTIMAL HARDHEAD SPAWNING RANGE							
Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	1 (6.7%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	3 (20.0%)	0 (0.0%)
Unfavorable	9 (60.0%)	6 (40.0%)	5 (33.3%)	5 (33.3%)	4 (26.7%)	5 (33.3%)	1 (6.7%)
57.2-78.8°F COMMONLY OBSERVED RANGE FOR NON-SPAWNING ADULT HARDHEAD							
Keswick Dam							
Favorable	0 (0.0%)	1 (1.7%)	0 (0.0%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	2 (3.3%)	0 (0.0%)	0 (0.0%)	3 (5.0%)	2 (3.3%)
Red Bluff Diversion Dam							
Favorable	10 (16.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (6.7%)	5 (8.3%)
Unfavorable	5 (8.3%)	3 (5.0%)	3 (5.0%)	4 (6.7%)	5 (8.3%)	3 (5.0%)	1 (1.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Seasonal operations impact on native minnows would mostly be negligible based on the CalSim 3 flows and temperature analysis with a few exceptions. Alternative 1 relative to the No Action Alternative is expected to have minimal impacts to native minnows due to differences in flow. Under Alternative 1 compared to the No Action Alternative, water temperatures in the Sacramento River at RBDD would likely have an adverse impact on hardhead spawning and both beneficial and adverse impacts on non-spawning hardhead. Water temperature related impacts on Sacramento splittail and hitch are likely negligible below Keswick Dam and at RBDD.

O.4.16.2 Clear Creek

Hardhead

According to Moyle et al. 2015, hardhead mainly occupy canyon reaches and deep pools in Clear Creek. Hardhead are one of the non-target species regularly caught in the RSTs in lower Clear Creek (Schraml and Chamberlain 2019a, 2019b, 2020, and 2021). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986). They migrate upstream and into tributary streams as far as 45 miles (72.4 km) to spawning sites.

Potential Changes to Hardhead from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning the CalSim 3 modeling results for flows in Clear Creek show that throughout the full simulation period average flows in Clear Creek would be substantially reduced. Under Alternative 1 average flows in Clear Creek ranged from 50 cfs (May) to 95 cfs (December), which represent a reduction in average flows compared to the No Action Alternative that ranged from a 50% reduction (December) to a 74% reduction (April/May) (Table O-23). With such a reduction in flows, hardhead would likely not utilize Clear Creek for spawning and rearing.

Hardhead are present in Clear Creek all months of the year. During the full simulation period and for all months utilizing the CalSim3 modeling results, average flows under Alternative 1 had a range from 48 cfs (September) to 95 cfs (December). The difference in average flows under Alternative 1 compared to the No Action Alternative had a range from 49% lower (November) to 84% lower (June), with a substantial reduction in flows occurring in all months (Table O-23). The proportion of hardhead already occupying Clear Creek would be adversely affected by a reduction in flows, due to crowding and lack of prey availability.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 64°F optimal water temperature range for hardhead spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 57.2°F to 78.8°F commonly observed range of temperatures for hardhead spawning year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 307 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-103. Table O-103, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 59-64°F optimal hardhead spawning range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results (Table O-103). For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there was one combination (1.7%) with favorable results and no

combinations (0%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on native minnows in Clear Creek.

Table O-103. Summary of Results for Water Temperature Analyses for Native Minnow Spawning and Non-spawning Adults in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
59-64°F OPTIMAL HARDHEAD SPAWNING RANGE							
Clear Creek below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
57.2-78.8°F COMMONLY OBSERVED RANGE FOR NON-SPAWNING ADULT HARDHEAD							
Clear Creek below Whiskeytown Dam							
Favorable	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are likely negligible impacts of seasonal operations on hardhead in Clear Creek based on temperature and simulated flow analysis for Alternative 1 compared to the No Action Alternative. Both the flow and temperature analysis show that Alternative 1 would have little to no difference in habitat suitability for all stages of hardhead compared to the No Action Alternative.

O.4.16.3 Lower American River

Hardhead and Sacramento Splittail

- **Hardhead:** The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are fairly common in the lower reaches of the lower American River. Hardhead are fairly common year-round in the lower reaches of the lower American River (Moyle 2002). Although migratory behavior of hardhead in the lower American River individuals is unknown, individuals from other large rivers, such as the Sacramento River, migrate into tributary streams during April and May. Hardhead typically spawn between April and May (Moyle 2002). Although hardhead early life history is largely

unknown, young individuals likely remain along stream edges with dense cover and move into deeper water as they grow, which allows migrants to move back downstream in the current (Moyle 2002).

- **Sacramento Splittail:** Splittail likely spawn in the lower reaches of the lower American River (Sommer et al. 2008; Moyle et al. 2004). Because upstream migration is more directed and fish tend to swim farther upstream during wet years (Moyle 2002), more individuals are expected to use the lower American River in wet years. Although juvenile splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks of rearing on floodplain habitat (Bureau of Reclamation 2008). Most juveniles move downstream into the Delta from April to August (Meng and Moyle 1995). The primary factor potentially limiting the lower American River population of Sacramento splittail is availability of inundated floodplains for spawning and rearing habitats (Moyle et al. 2004).

Potential Changes to Hardhead and Sacramento Splittail from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning for flows in the lower American River below Nimbus the CalSim3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 1 average flows in the lower American River below Nimbus Dam ranged from 3,581 cfs (May) to 6,616 cfs (February). The difference in average flows under Alternative 1 compared to the No Action Alternative had a range from a 4% reduction (March) to a 6% increase (April) (Table O-25). The minimal differences in flows would likely have a negligible effect on native minnow migration and spawning under Alternative 1 compared to the No Action Alternative.

During all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 1 range from about 551 cfs for September of critically dry water years to about 12,306 cfs for February of wet water years (Table O-25). For all water year types, CalSim 3 results indicate that differences in average flows during January through December would generally be minimal (up to 5%) under Alternative 1 compared to the No Action Alternative, with a few exceptions. Flows under Alternative 1 for all water years would decrease in July, September, and November (up to 20%) and increase in April and June (up to 16%) (Table O-25). Hardhead are the only native minnow known to be present in the lower American River for all months of the year. The minimal difference in lower American River below Nimbus Dam flows would likely have a negligible effect on hardhead under Alternative 1 compared to the No Action Alternative.

During the December through May period for adult migration and spawning for flows in the lower American River at H street the CalSim3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 1 average flows in the lower American River at H street ranged from 3,452 cfs (May) to 6,604 cfs (February). The difference in average flows under Alternative 1 compared to the No Action Alternative had a range from a 4% reduction (March) to a 6% increase (April) (Table O-26). The minimal differences in flows would likely have a negligible effect on native minnow migration and spawning under Alternative 1 compared to the No Action Alternative.

During all months, CalSim 3 estimates of mean monthly flows at H Street under Alternative 1 range from about 689 cfs for September of critically dry water years to about 12,283 cfs for February of wet water years (Table O-26). For all water year types, CalSim 3 results indicate that differences in average flows during January through December would generally be minimal (up to 5%) under Alternative 1 compared to the No Action Alternative, with a few exceptions. Flows under Alternative 1 for all water years would decrease in July, August, September, and November (up to 22%) and increase in April and June (up to 17%) (Table O-26). Hardhead are the only native minnow known to be present in the lower American River for all months of the year. The minimal differences in lower American River at H Street flows would likely have a negligible effect on hardhead under Alternative 1 compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 75°F water temperature range observed for Sacramento splittail suitable spawning during February through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 87 for Hazel Avenue and Table 88 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the outside the 59°F to 64°F water temperature optimal range for hardhead spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 89 for Hazel Avenue and Table 90 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the outside the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 91 for Hazel Avenue and Table 92 for Watt Avenue.

Results for these three analyses are summarized in Table O-104. Table O-104, as described in Section O.4.16.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 45°F to 75°F water temperature range observed for suitable spawning for Sacramento splittail under Alternative 1, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at both Hazel Avenue and Watt Avenue (Table O-104). There were also no month-water year type combinations (0% of total combinations during the period) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 59°F to 64°F water temperature optimal range for hardhead spawning, there were one and zero month-water year type combinations (6.7% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and two month-water year type combinations (6.7% and 13.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were one and four month-water year type combinations (1.7% and 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and four month-water year type combinations (3.3% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that Alternative 1 would have negative water temperature-related effects on native minnow spawning and non-spawning presence in the lower American River in the lower American River at Hazel Avenue and Watt Avenue.

Table O-104. Summary of Results for Water Temperature Analyses for Spawning Adult Hardhead for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
45°F–75°F TEMPERATURE RANGE OBSERVED FOR SACRAMENTO SPLITTAIL SUITABLE SPAWNING							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
59°F–64°F OPTIMAL RANGE FOR HARDHEAD SPAWNING							
Hazel Avenue							
Favorable	1 (6.7%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	4 (26.7%)	1 (6.7%)
Unfavorable	1 (6.7%)	2 (13.3%)	1 (6.7%)	2 (13.3%)	2 (13.3%)	1 (6.7%)	1 (6.7%)
Watt Avenue							
Favorable	0 (0.0%)	1 (6.7%)	1 (6.7%)	2 (13.3%)	1 (6.7%)	0 (0.0%)	2 (13.3%)
Unfavorable	2 (13.3%)	2 (13.3%)	0 (0.0%)	2 (13.3%)	3 (20.0%)	5 (33.3%)	1 (6.7%)
57.2°F–78.8°F OBSERVED WATER TEMPERATURE RANGE FOR NON-SPAWNING ADULT HARDHEAD							
Hazel Avenue							
Favorable	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (5.0%)	3 (5.0%)
Unfavorable	2 (3.3%)	2 (3.3%)	1 (1.7%)	2 (3.3%)	2 (3.3%)	1 (1.7%)	1 (1.7%)
Watt Avenue							
Favorable	4 (6.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	0 (0.0%)	2 (3.3%)	2 (3.3%)
Unfavorable	4 (6.7%)	2 (3.3%)	2 (3.3%)	3 (5.0%)	3 (5.0%)	5 (8.3%)	2 (3.3%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There are likely negligible and adverse impacts of seasonal operations on native minnow in the lower American River based on the difference in simulated flows for Alternative 1 compared to the No Action Alternative. However, based off the temperature analysis for the lower American River at Watt Avenue, the frequency of sub-optimal temperatures for spawning hardhead would be higher under Alternative 1 compared to the No Action Alternative. Water temperature related impacts on Sacramento splittail are likely negligible in the lower American River at Watt Ave and Hazel Ave. Under Alternative 1 differences in flows are minimal, so adult migration and spawning would likely be unaffected, but the proportion of native minnows remaining in the lower American River would be adversely impacted by sub-optimal temperatures compared to the No Action Alternative.

O.4.16.4 Stanislaus River

Hardhead

The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are a frequent catch in the lower Stanislaus River (Bradbury and Hickey 2019). The Stanislaus River compared to other systems in the San Joaquin watershed has higher discharge and albeit slightly cooler water for most of the year. Due to the more stream-like conditions the Stanislaus River is occupied by many native fish including hardhead. The increased discharge has also limited many non-native fishes, concentrating them in the lower reaches. Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).

Potential Changes to Hardhead from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning for flows in the Stanislaus River at the confluence with the San Joaquin, the CalSim3 modeling results show that throughout the full simulation period differences in flows are similar with greater flows under Alternative 1 most months. Under Alternative 1, average flows in the Stanislaus River at the confluence ranged from 528 cfs (December) to 1,300 cfs (May). The difference in average flows under Alternative 1 compared to the No Action Alternative ranged from a 1% reduction (January) to a 9% increase (May) (Table O-28). The change in flows under Alternative 1 compared to the No Action Alternative would likely have a negligible to positive effect on hardhead migration and spawning.

During all months, and for the full simulation period CalSim3 estimates of mean monthly flows for the Stanislaus River at the confluence of the San Joaquin River under Alternative 1 range from 420 cfs (July) to 1,300 cfs (May). The difference in average flows under Alternative 1 compared to the No Action Alternative ranged from a 25% reduction (October) to a 23% increase (June) (Table O-28). Hardhead are present in the Stanislaus River for all months of the year. Except for a few months in the fall, increased flows under Alternative 1 would likely have a beneficial effect on hardhead in the Stanislaus River.

During the December through May period for adult migration and spawning for flows in the Stanislaus River below Goodwin Dam the CalSim3 modeling results show that throughout the full simulation period differences in flows are similar with greater flows under Alternative 1 most months. Under Alternative 1 average flows in the Stanislaus River below Goodwin Dam ranged from 550 cfs (December) to 1,196 cfs (May). The difference in average flows under Alternative 1 compared to the No Action Alternative ranged from a 4% reduction (March) to a 11% increase (December/May) (Table O-27). The increase in flows under Alternative 1 compared to the No Action Alternative would likely have a negligible to beneficial effect on hardhead migration and spawning.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the Stanislaus River below Goodwin Dam under Alternative 1 range from 276 cfs (July) to 1,196 cfs (May) (Table O-28).The difference in average flows under Alternative 1 compared to the No Action Alternative ranged from a 56% reduction (October) to a 29% increase (November). Hardhead are present in the Stanislaus River for all months of the year. Except for a few months in the fall, increased flows under Alternative 1 compared to the No Action Alternative would likely have a beneficial effect on hardhead in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the outside the 59°F to 64°F water temperature optimal range for hardhead spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 868 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the outside the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 69 for Orange Blossom Bridge.

Results for these two analyses are summarized in Table O-105. Table O-105, as described in Section O.4.16.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 59°F to 64°F water temperature optimal range for hardhead spawning under Alternative 1, there was one month-water year type combination (6.7%) with favorable results and two month-water year type combinations (13.3%) with unfavorable results at Orange Blossom Bridge (Table O-105). For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were five month-water year type combinations (8.3%) with favorable results and four month-water year type combinations (6.7%) with unfavorable results at Orange Blossom Bridge.

These results suggest that Alternative 1 would have negative water temperature-related effects on native minnows in the Stanislaus River at Orange Blossom Bridge.

Table O-105. Summary of Results for Water Temperature Analyses for Spawning and Non-spawning Adult Hardhead for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
59°F–64°F OPTIMAL RANGE FOR SPAWNING							
Orange Blossom Bridge							
Favorable	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)
Unfavorable	2 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	0 (0.0%)
57.2°F–78.8°F OBSERVED WATER TEMPERATURE RANGE FOR NON-SPAWNING ADULTS							
Orange Blossom Bridge							
Favorable	5 (8.3%)	2 (3.3%)	2 (3.3%)	2 (3.3%)	2 (3.3%)	3 (5.0%)	2 (3.3%)
Unfavorable	4 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Simulated flows under Alternative 1 compared to the No Action were minimal and would likely have negligible impacts to hardhead. However, based off the temperature analysis for the Stanislaus River at Orange Blossom bridge, the frequency of sub-optimal temperatures for both spawning adults and non-spawning adults/juveniles would be higher under Alternative 1 compared to the No Action Alternative. Under Alternative 1 differences in flows are minimal, so adult migration and spawning would likely be unaffected, but the proportion of hardhead remaining in the Stanislaus River would be adversely impacted by sub-optimal temperatures as compared to the No Action Alternative.

O.4.16.5 San Joaquin River

Sacramento Splittail, Hardhead, and Sacramento Hitch

- **Sacramento Splittail:** Historically, Sacramento splittail were widespread in the San Joaquin River and found upstream to Tulare and Buena Vista lakes, where they were harvested by native peoples (Moyle et al. 2004). Today, Sacramento splittail likely swim up the San Joaquin River to Salt Slough during wet years (Baxter 1999). During dry years, Sacramento splittail are uncommon in the San Joaquin River downstream of the Tuolumne River (Moyle et al. 2004).

The population of Sacramento splittail is largely influenced by extent and period of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Moyle et al. 2004).

- **Hardhead:** In the San Joaquin drainage, hardhead are present throughout tributary streams but are largely absent from the valley reaches of the San Joaquin River (Moyle et al. 2015, Moyle and Nichols 1973, Saiki 1984). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).
- **Sacramento Hitch:** Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta, but are now absent from the San Joaquin River and tributaries between Friant Dam and the Merced River (Moyle et al. 2015). Sacramento hitch are occasionally captured in low numbers in the lower San Joaquin River in the Mossdale trawl monitoring program (Interagency Ecological Program et al. 2022).

Potential Changes to Sacramento Splittail, Sacramento Hitch, and Hardhead from Seasonal Operations

During the December through May period for adult migration and spawning for flows in the San Joaquin at Vernalis the CalSim3 modeling results show that throughout the full simulation period differences in flows are minimal. Under Alternative 1 average flows in the San Joaquin at Vernalis ranged from 2,897 cfs (December) to 6,553 cfs (February). The difference in average flows under Alternative 1 compared to the No Action Alternative had a range from 0% (January) to a 3% increase (May) (Table O-29). With minimal differences in flows native minnow migration and spawning would likely have a negligible effect under Alternative 1 compared to the No Action Alternative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the San Joaquin at Vernalis under Alternative 1 range from 1,486 cfs (September) to 6,553 cfs (February). The difference in average flows under Alternative 1 compared to the No Action Alternative ranged from a 6% reduction (October) to a 7% increase (July/August) (Table O-29). Presence of native minnows in the San Joaquin are not well known, but it is likely that species are present year-round. The change in flow under Alternative 1 compared to the No Action Alternative would likely have a negligible effect on native minnows.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on native minnows in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

<u>Summary</u>

Based off the Calsim3 flow analysis differences in flow under Alternative 1 would be minimal. Many native minnows likely use the San Joaquin and its tributaries for spawning and rearing, and adequate flow is also necessary for spawning adults to access spawning areas. The difference in flow under Alternative 1 compared to the No Action Alternative would likely have negligible

impacts to native minnow. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.4.16.6 Bay-Delta

Hardhead, Sacramento Hitch, and Sacramento Splittail

- **Hardhead:** The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are present in low abundance in the San Francisco Estuary and Delta. Electrofishing surveys in parts of the Bay-Delta in the 1980's and 2000's captured small numbers of hardhead (Brown and Michniuk 2007). Retrieval of hardhead at the SWP/CVP south Delta fish salvage facilities remain relatively low (California Department of Water Resources 2020).
- **Sacramento Hitch:** The species is distributed in the Sacramento River Basin, in low numbers in the San Joaquin River Basin, and occasionally captured during monitoring programs in the Delta (Moyle et al. 2015; Interagency Ecological Program et al. 2022). Monitoring data suggests year-round presence in the Delta (Interagency Ecological Program et al. 2022).
- **Sacramento Splittail:** Adult Sacramento splittail typically migrate upstream from brackish areas in January and February and spawn in freshwater, particularly in inundated floodplains when they are available, in March and April (Sommer et al. 1997; Moyle et al. 2004; Sommer et al. 2008). A substantial amount of splittail spawning occurs in the Yolo and Sutter Bypasses and the Cosumnes River area of the Delta (Moyle et al. 2004).

  Although juvenile Sacramento splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks or months of rearing in floodplain habitats along the rivers (Feyrer et al. 2006). Juveniles move downstream into the Delta from April to August (Meng and Moyle 1995; Feyrer et al. 2005). Sacramento splittail recruitment is largely limited by extent and period of inundation of floodplain spawning habitats, with abundance observed to spike following wet years and dip after dry years (Moyle et al. 2004).

Potential Changes to Sacramento Splittail, Sacramento Hitch, and Hardhead from Seasonal Operations

<u>CalSim 3 Flows</u>

For many species of native minnow, changes in export flows can lead to higher levels of entrainment which can potentially influence population dynamics. Certain species such as Sacramento splittail are known to utilize the Delta for many portions of their life history so export flows into the Delta will have a strong effect on these fish by limiting habitat, prey availability and access to spawning areas. Since many native minnows occupy the Delta year-round, export flows were examined for all months.

For the full simulation period, CalSim3 estimates of Delta outflow would be reduced under Alternative 1 compared to the No Action Alternative for most months. CalSim3 estimates of average Delta outflow have a range from 3,858 (August) cfs to 56,684 cfs (February) for Alternative 1 and for the full simulation period. Differences in average outflow under Alternative

1 as compared to the No Action Alternative would be from a 39% reduction (September) to a 10% increase (June) (Table O-20). June is the only month with an increase in Delta outflow under Alternative 1, all other months would have a decrease in outflow ranging from 1% to 39% for the full simulation period (Table O-20). Although differences in average Delta outflow are minimal, substantial reductions in outflow occurring in below normal, dry, and critically dry water year types would likely have a strong negative effect on native minnows. Substantial reductions in outflow would also occur in wet water year types, but with flows still remaining generally high, the effect would be somewhat negligible. Overall, Alternative 1 would likely have an adverse effect on native minnows in the Delta by reducing outflow as compared to the No Action Alternative.

CalSim3 estimates of mean monthly average flow for the total exports of SWP and CVP under Alternative 1 range from 1,556 cfs for August of critically dry water years to about 12,805 cfs for January of wet water years (Table O-19). For the full simulation period, CalSim3 results indicate that differences in average export flows during January through December would substantially increase (up to 52%) under Alternative 1 compared to the No Action Alternative. The difference in average export flows under Alternative 1 compared to the No Action Alternative for the full simulation period ranged from a 5% reduction (November) to a 52% increase (January) (Table O-19). With a substantial increase in exports and a reduction in Delta outflow native minnows would likely be impacted adversely for all life stages under Alternative 1 compared to the No Action Alternative.

Summary

Certain species such as Sacramento splittail are known to utilize the Delta for many portions of their life history so flows into the Delta will have a strong impact on these fish by limiting habitat, prey availability and access to spawning areas.

Although differences in average Delta outflow are minimal, substantial reductions in outflow occurring in below normal, dry, and critically dry water year types would likely have a substantial adverse impact on native minnows. Substantial reductions in outflow would also occur in wet water year types, but with outflow remaining generally high, the impact would be negligible for wet water year types. Overall, Alternative 1 would likely have an adverse impact on native minnows in the Delta by reducing outflow compared to the No Action Alternative.

The substantial increase in exports and a reduction in Delta outflow native minnows would likely have an adverse impact on all life stages under Alternative 1 as compared to the No Action Alternative due to increased entrainment and unfavorable habitat conditions in the Delta.

Potential Changes to Entrainment of Sacramento Splittail, Sacramento Hitch, and Hardhead

Sacramento Splittail: Salvage Density

Predictions from the salvage density model for Sacramento splittail include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 92% greater for the above normal water year types (Table O-106). Predicted average

monthly loss of Sacramento splittail at CVP Jones Pumping Plant for all months of the year and all water year types, Alternative 1 was greater than predicted average monthly loss under the No Action Alternative, up to 13% greater for critically dry water year types (Table O-107). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Table O-106. Predicted Average Monthly Loss of Sacramento Splittail at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	51585	78618 (52%)	76135 (48%)	75999 (47%)	75998 (47%)	76133 (48%)	24186 (-53%)	74538 (44%)	12: Jan–Dec
Above Normal	26368	50682 (92%)	42780 (62%)	42809 (62%)	38775 (47%)	38337 (45%)	17723 (-33%)	42840 (62%)	12: Jan–Dec
Below Normal	602	792 (32%)	611 (2%)	627 (4%)	620 (3%)	616 (2%)	416 (-31%)	594 (-1%)	12: Jan–Dec
Dry	47	77 (64%)	59 (27%)	59 (26%)	49 (5%)	49 (4%)	45 (-5%)	60 (28%)	12: Jan–Dec
Critically Dry	21	29 (39%)	21 (2%)	20 (-5%)	20 (-4%)	20 (-4%)	21 (2%)	22 (4%)	11: Jan–Sep, Oct–Dec

Table O-107. Predicted Average Monthly Loss of Sacramento Splittail at Jones by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	647664	650904 (1%)	652040 (1%)	651787 (1%)	650856 (1%)	651003 (0%)	124757 (-81%)	654195 (1%)	12: Jan–Dec
Above Normal	525515	579526 (10%)	534514 (2%)	534114 (2%)	520915 (-1%)	518181 (-1%)	89462 (-83%)	536227 (2%)	12: Jan–Dec
Below Normal	6477	7043 (9%)	6582 (2%)	6255 (-3%)	6085 (-6%)	5944 (-8%)	1371 (-79%)	6671 (3%)	12: Jan–Dec
Dry	132	134 (2%)	113 (-14%)	114 (-13%)	115 (-13%)	116 (-12%)	17 (-87%)	117 (-11%)	12: Jan–Dec
Critically Dry	4	4 (13%)	4 (-2%)	4 (1%)	4 (4%)	4 (3%)	2 (-56%)	4 (1%)	6: Jan, March, May, July, Oct–Nov

Hardhead: Salvage Density

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on hardhead entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Predictions from the salvage density model for hardhead include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Whereas at the CVP Jones Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of hardhead of Alternative 1 compared to the No Action Alternative at SWP Banks Pumping Plant were greater all water year types, except in dry water year types when no fish are expected (Table O-108 and Table O-109). At the SWP Banks Pumping Plant predicted average monthly loss was between 18% and 208% greater in April of wet and above normal water year, respectively (Table O-108). Historical loss of hardhead at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Table O-108. Predicted Average Monthly Loss of Hardhead at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	1	1 (18%)	1 (16%)	1 (16%)	1 (7%)	1 (7%)	0 (-65%)	1 (15%)	1: April
Above Normal	0	1 (208%)	1 (178%)	1 (177%)	0 (49%)	0 (49%)	0 (39%)	1 (177%)	1: April
Below Normal	0	0	0	0	0	0	0	0	No Fish
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	2	2 (19%)	2 (11%)	2 (23%)	3 (35%)	3 (35%)	9 (372%)	2 (8%)	1: September

Table O-109. Predicted Average Monthly Loss of Hardhead at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	0	0	0	0	0	0	0	0	No Fish
Above Normal	0	0	0	0	0	0	0	0	No Fish
Below Normal	0	0	0	0	0	0	0	0	No Fish
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Sacramento Hitch: Salvage Density

Predictions from the salvage density model for Sacramento hitch include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Alternative 1 had greater than predicted average monthly loss compared to the No Action Alternative for all water year types. Predicted average monthly loss at Banks under Alternative 1 ranged from 9% higher for below normal water year types to 208% higher for above normal water year types, there was no predicted loss for critically dry water year types (Table O-110). Predicted average monthly loss of Sacramento hitch at CVP Jones Pumping Plant for the months of March through April Alternative 1 was greater or equal than predicted average monthly loss under the No Action Alternative for wet, below normal, dry, and critically dry water year types. Predicted loss for above normal water year types was lower for Alternative 1 as compared to the No Action Alternative. The range of predicted loss for Sacramento hitch at Jones under Alternative 1 compared to the No Action Alternative was from 3% lower in above normal water year types to 18% higher for below normal water year types. No fish were predicted to be lost in dry and critically dry water year types. It should be noted that loss of Sacramento hitch at both facilities is rare and infrequent, with such low values of predicted loss, the percent differences may not be representative. (Table O-111). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Table O-110. Predicted Average Monthly Loss of Sacramento Hitch at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	1	2 (18%)	2 (16%)	2 (16%)	1 (7%)	1 (7%)	0 (-65%)	2 (15%)	1: April
Above Normal	0	1 (208%)	1 (178%)	1 (177%)	0 (49%)	0 (49%)	0 (39%)	1 (177%)	1: April
Below Normal	2	2 (9%)	2 (2%)	2 (-2%)	2 (4%)	2 (4%)	1 (-36%)	2 (1%)	12: Jan–Dec
Dry	1	1 (33%)	1 (-5%)	1 (-5%)	1 (-1%)	1 (3%)	1 (12%)	1 (-4%)	1: Oct
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Table O-111. Predicted Average Monthly Loss of Sacramento Hitch at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	3	3 (1%)	3 (10%)	3 (11%)	3 (-10%)	3 (-11%)	1 (-80%)	3 (12%)	1: April
Above Normal	3	3 (-3%)	3 (0%)	3 (0%)	2 (-33%)	2 (-33%)	0 (-85%)	3 (0%)	1: April
Below Normal	1	1 (18%)	1 (0%)	1 (5%)	1 (-33%)	1 (-36%)	1 (-32%)	1 (2%)	1: March
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Summary

With higher export for most months and water year types, levels of entrainment are expected to be higher for Alternative 1 compared to the No Action Alternative. Although loss of certain species such as Sacramento hitch are generally small and infrequent, for all species of native minnows, predicted salvage was higher for most months and water year types under Alternative 1 compared to the No Action Alternative.

O.4.17 Pacific Lamprey

O.4.17.1 Trinity River

Spawning and Egg Incubation

Pacific lamprey typically spawn from March through June, when daily mean water temperatures range from 50–64°F, with peak spawning occurring typically occurring in April and May and when water temperatures are approximately 57–59°F (Stone 2006, Brumo et al. 2009). Redds are typically constructed in gravel and cobble substrates within pool and run tailouts and low gradient riffles (Stone 2006, Brumo et al. 2009). Eggs are deposited in the redd and hatch after approximately 15 days, depending on water temperatures (Meeuwig et al. 2005, Brumo 2006). Egg-sac larvae spend another 15 days in redds before emergence. Temperatures in excess of 65°F during incubation have been shown to reduce embryo survival (Meeuwig et al. 2005). The effects analysis period for spawning and egg incubation in the Trinity River is March through July.

Potential Changes to Pacific Lamprey Spawning and Egg Incubation from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 to flows under the No Action Alternative. Differences in flow, most less than 5%, in March through July of below normal and wetter water year types, would be minor in reduction of the usable area of spawning and egg incubation habitat for Pacific lamprey, and could provide a minor increase in spawning habitat during above normal years. During the spawning window, Alternative 1 compared to the No Action Alternative is almost identical except for a reduction of flow greater than 5% in March during below normal water years. This reduction would still allow flows of 300 cfs and likely would have minor to negligible impacts on the availability of suitable spawning habitat or egg incubation.

Compared to the No Action Alternative, the December and February flow increases would either reduce monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain cooler than the suggested upper limit of 64°F water temperature to protect spawning Pacific lamprey in the reach from Lewiston Dam to the North Fork Trinity River. The flow reduction in March in below normal water years would increase monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative. However, this change would be unlikely to cause an exceedance of the upper temperature threshold suggested for spawning and egg incubation of Pacific Lamprey.

<u>Ammocoete Rearing and Emigration</u>

After emergence from redds, eyeless Pacific lamprey larvae, known as ammocoetes, settle out of the water column and burrow into fine silt and sand substrates, often containing organic matter. Ammocoetes rear in these habitats for 4–10 years. Water temperature requirements for the life stage are not well described. Ammocoetes have been observed to burrow in substrates in streams with water temperatures up to 80°F (Claire 2004), and upper temperature tolerances are estimated to be around 83°F (Whitesel and Uh 2022). After Pacific lamprey metamorphose to the macropthalmia stage, individuals migrate to the ocean typically in conjunction with high flow events between fall and spring, but migration can occur year-round. The effects analysis period

for ammocoete rearing is year-round and emigration is primarily fall through spring in the Trinity River.

Potential Changes to Pacific Lamprey Ammocoete Rearing and Emigration from Seasonal Operations

Differences in Trinity River flows between Alternative 1 and the No Action Alternative would occur in March of below normal and wet water years would be minor to unlikely to reduce the availability or suitability of ammocoete rearing habitat for Pacific lamprey. Monthly average flows under Alternative 1 compared to the No Action Alternative in March in below normal water years would still allow for flows of 300 cfs and would be unlikely to have detrimental effects to rearing habitat. Greater than 5% increases in flow under Alternative 1 compared to the No Action Alternative during wet and above normal years in winter months would provide increased water velocity encouraging downstream migration, and likely provide minor increased habitat availability of pools and side channels. Flows under Alternative 1 compared to the No Action Alternative during summer months are almost identical for ammocoete rearing and non-peak season emigration.

Compared to the No Action Alternative, the December and February flow increases would either reduce monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain cooler than the upper water temperature threshold suggested of 83°F for ammocoete rearing and emigration of Pacific lamprey in the reach from Lewiston Dam to the North Fork Trinity River. The flow reduction in March in below normal water years would increase monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative. However, this change would be unlikely to cause an exceedance of the upper temperature threshold suggested for Pacific lamprey, and would have negligible impacts on growth rates of ammocoetes.

Adult Upstream Migration and Holding

Adult Pacific lamprey typically enter freshwater from winter to early summer, but in the Klamath River adults have been reported to enter year-round (Petersen-Lewis 2009, Parker 2018). In general, adult Pacific lampreys have two life history types: ocean maturing where individuals likely spawn several weeks after entering freshwater, and stream maturing where individuals spend one year in freshwater prior to spawning (Clemens et al. 2013, Parker et al. 2019). In general, adult Pacific lamprey hold in interstitial spaces within large cobble and boulders and also in glides, runs, and riffles (Lampman 2011). Water temperature requirements for holding adult Pacific lampreys have not been fully evaluated, but adults have been observed in temperatures ranging from 60 to 84°F (Starecvich et al. 2014). The effects analysis period for adult upstream migration and holding in the Trinity River is year-round.

Potential Changes to Pacific Lamprey Adult Upstream Migration and Holding from Seasonal Operations

Under Alternative 1, seasonal operations in the Trinity River are expected to provide similar or better habitat conditions for adult Pacific lamprey upstream migration and holding than the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous

fish. During the winter Pacific lamprey upstream migration and holding period there would greater than 5% increase in flows in December compared to the No Action Alternative during wet years, February during above normal years, and a 5% decrease in flows in March during below normal years. The increase in flows in December and February would potentially provide minor benefits to upstream passage and holding habitat. The decrease in flow in March in below normal years would be minor to migration and holding habitat of adults as releases would decrease from 427 to 300 cfs. Monthly average flows during summer and fall months when Pacific lamprey adults are potentially holding will be similar to the No Action Alternative, with minor to almost identical flows at or above 300 cfs.

Compared to the No Action Alternative, the December and February flow increases would either reduce monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the upper water temperature suggested of 84°F for adult Pacific lamprey upstream migration and holding in the reach from Lewiston Dam to the North Fork Trinity River. The flow reduction in March in below normal water years would increase monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative. However, this change would be unlikely to cause an exceedance of the upper temperature threshold suggested for Pacific lamprey, and would have negligible impacts on adult Pacific lamprey migration and holding.

O.4.17.2 Sacramento River

Spawning and Egg Incubation

Pacific lamprey construct redds in shallow water (about 0.5 to 3.5 feet or 0.15 to 1 meter) gravel habitats in the upper river and spawning occurs from March through July with peak spawning typically occurring in early April (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015). The eggs and pro-larvae incubate for about 1 to 1.5 months. Water flows and temperature effects on eggs are March-August but are largely April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

<u>CalSim 3 Flows</u>

CalSim 3 estimates for monthly flows in the Sacramento River at Red Bluff Diversion Dam and below Keswick Dam for Alternative 1 compared to the No Action Alternative are a mix of increases and decreases (Table O-14 and Table O-15). Impacts on Pacific lamprey spawning are likely to be somewhat mixed as well. Flows during spawning months are likely to have minor changes below Red Bluff Diversion Dam, outside of some water year types in June and July, which see some increases, and August, which has decreases. Flow values below Keswick Dam during spawning are largely increased compared to the No Action Alternative. Similarly to RBDD, August is projected to have decreased flows at the end of the spawning period which may not have as great of an impact as a decrease during peak spawning months. Overall, flow changes under Alternative 1 are likely to have slight beneficial to negligible impact on Pacific lamprey spawning. Slight increases in spawning months below Keswick Dam could have a slight beneficial impact, as several of these increases come during peak spawning and egg incubation time in dry and critically dry years, but flows are expected to remain high enough at both

locations year-round that spawning and egg incubation should not be greatly impacted by either the slight increases in spawning months or the August decreases.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 295 for Keswick Dam and Table 296 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-112. Table O-112, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at Keswick Dam or RBDD (Table O-112). There were three and one combinations (12.0% and 4.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 1 on Pacific lamprey spawning and egg incubation in the Sacramento River.

Table O-112. Summary of Results for Water Temperature Analyses for Pacific Lamprey Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
50°F–64°F OBSERVED RANGE OF HIGH SURVIVAL AND LOW OCCURRENCE EMBRYONIC DEVELOPMENTAL ABNORMALITIES							
Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	3 (12.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (8.0%)	1 (4.0%)
Unfavorable	1 (4.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have possible minor beneficial to minor adverse impacts on Pacific lamprey spawning due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have adverse impacts on Pacific lamprey spawning in the Sacramento River due to differences in water temperature.

Ammocoete Rearing and Emigration

After spawning, Pacific lamprey embryos remain buried in gravel for a period of weeks before emerging as ammocoetes and burying themselves in sediments to filter-feed. Ammocoetes select habitats that are often off-channel, with low flow velocity and shallow depths; therefore, they are vulnerable to stranding by reductions in water level. After 3 or more years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean. Data from rotary screw trapping at sites on the mainstem Sacramento River indicate that emigration of Pacific lamprey peaks from early winter through early summer, but some emigration is observed year-round at both the RBDD and the GCID diversion dam (Hanni et al. 2006).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River at Red Bluff Diversion Dam and below Keswick Dam for Alternative 1 compared to the No Action Alternative are a mix of increases and decreases (Table O-14 and Table O-15). Impacts on Pacific lamprey ammocoete rearing are likely to be somewhat mixed as well. Ammocoete rearing would possibly benefit from the slight increases in dry and critically dry summer months below Keswick Dam, while flow decreases in some fall months at both locations could have a slight adverse impact. Overall, beneficial effects are possible in some summer months and adverse impacts are possible in some fall months, but flows are expected to be high enough that riverbed rearing habitat should not be threatened, and all impacts should therefore be minimal. Juvenile emigration would likely also see minimal impacts, as flows are consistently high enough to allow outmigration and survival is unlikely to be threatened.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific Lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 298 for Keswick Dam and Table 299 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-113. Table O-113, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at both Keswick Dam and RBDD (Table O-113). These results suggest that there would be negligible water temperature-related effects of Alternative 1 on Pacific lamprey ammocoete rearing and emigration in the Sacramento River.

Table O-113. Summary of Results for Water Temperature Analyses for Pacific Lamprey Ammocoete Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
72°F UPPER LIMIT FOR HIGH SURVIVAL AND LOW OCCURRENCE OF DEVELOPMENTAL ABNORMALITIES							
Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey ammocoete rearing, and no impact on juvenile emigration due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and juvenile emigration due to differences in water temperature.

O.4.17.3 Clear Creek

Spawning and Egg Incubation

Pacific lamprey usually spawn in Clear Creek from March through July, depending on water temperatures and local conditions such as seasonal flow regimes. The adults construct redds similar to steelhead redds, and eggs incubate for 11 to 30 days, depending on the water temperature, prior to hatching. Although the extent of spawning is unknown, the species spawns in Clear Creek as evidenced by ammocoetes routinely collected in the screw trap at RM 1.7. Effects from water flows and temperature on eggs are likely felt March-August, and they likely peak in accordance with peak spawning April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in Clear Creek below Whiskeytown Dam are decreased for Alternative 1 compared to the No Action Alternative in all months across all water year types (Table O-23). This across-the-board decrease would likely have adverse impacts on Pacific lamprey spawning. With very low flows throughout the spring and summer, it is possible that redds could be dewatered and that spawning would be adversely affected. Impacts from changes in flows under Alternative 1 compared to the No Action Alternative on Pacific lamprey spawning are likely to be adverse.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 288 for Clear Creek below Whiskeytown Dam.

Results for the analysis are summarized in Table O-114. Table O-114, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were 16 month-water year type combinations (66.7% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable results below Whiskeytown Dam (Table O-114). These results suggest that there would be positive water temperature-related effects of Alternative 1 on Pacific lamprey spawning and egg incubation in Clear Creek.

Table O-114. Summary of Results for Water Temperature Analyses for Pacific Lamprey Spawning and Egg Incubation in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
50°F–64°F OBSERVED RANGE OF HIGH SURVIVAL AND LOW OCCURRENCE EMBRYONIC DEVELOPMENTAL ABNORMALITIES							
Below Whiskeytown Dam							
Favorable	16 (66.7%)	3 (12.5%)	3 (12.5%)	4 (16.7%)	4 (16.7%)	8 (33.3%)	5 (20.8%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have adverse impacts on Pacific lamprey spawning due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have beneficial impacts on Pacific lamprey spawning and egg incubation in Clear Creek due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey rearing takes place over multiple years. Hatched embryos remain in the gravel for up to one more month as gill slits develop. The ammocoetes then spend three to seven years in soft sediments as filter feeders (U.S. Fish and Wildlife Service 2019). Once ammocoetes have become juveniles, they begin to migrate towards the ocean in spring and possibly early summer. Impacts from water temperature and flow on larval and juveniles are year-round due to their prolonged rearing in their home waters, with spring and summer flows during migratory periods being important as well.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in Clear Creek below Whiskeytown Dam are decreased for Alternative 1 compared to the No Action Alternative in all months across all water year types (Table O-23). Pacific lamprey ammocoete rearing would likely see adverse impacts under Alternative 1. As ammocoetes spend a period of years rearing upstream, low flows across all months in all water year types would have a persistent adverse impact on rearing and could affect survival of individuals. Juvenile emigration would likely also see adverse impacts, since the flow decreases for Alternative 1 relative to the No Action Alternative occur during the peak outmigration period, which could hinder emigration.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific Lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 291 for Clear Creek below Whiskeytown Dam.

Under Alternative 1 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-115). These results suggest that there would be negligible water temperature-related effects of Alternative 1 on Pacific lamprey ammocoete rearing and emigration in Clear Creek.

Table O-115. Summary of Results for Water Temperature Analyses for Pacific Lamprey Ammocoete Rearing and Emigration in Clear Creek for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
72°F UPPER LIMIT FOR HIGH SURVIVAL AND LOW OCCURRENCE OF DEVELOPMENTAL ABNORMALITIES							
Below Whiskeytown Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have an adverse impact on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration due to differences in water temperature.

O.4.17.4 Lower American River

Spawning and Egg Incubation

Hannon and Deason (2008) documented Pacific lamprey spawning in the lower American River from early January to late May, with peak spawning typically occurring in early April. Redds are built in shallow water environments and eggs incubate for several weeks before larvae emerge. Water temperature and flow effects on eggs are likely January-June, with peak effects April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 1 compared to the No Action Alternative are a mix of increases and decreases, depending on water year type and month (Table O-25 and Table O-26). Impacts on Pacific lamprey spawning would likely be more beneficial than adverse, with more flow increases than decreases during the spawning period of January through June. June sees flow increases for all water year types, which could have a beneficial impact on late spawning and egg survival from the end of the peak spawning period. April flows in critically dry years would also see a large increase, which would likely benefit Pacific lamprey spawning as well. However, some months would see flow decreases, which might have adverse impacts on spawning. March would see flow decreases in all water year types, which could have an adverse impact on spawning. Overall, impacts of flow changes due to Alternative 1 on Pacific lamprey spawning would be mixed, but likely with more beneficial impacts than adverse ones.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities during March through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 79 for Hazel Avenue and Table 80 for Watt Avenue.

Results for the analysis are summarized in Table O-116. Table O-116, as described in Section O.4.17.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities for Pacific lamprey spawning and egg incubation under Alternative 1, there were three and zero month-water year type combinations (12.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-116). There were three month-water year type combinations (12.0%) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively.

These results suggest Alternative 1 would have positive and negative water temperature-related impacts to Pacific lamprey spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Table O-116. Summary of Results for Water Temperature Analyses for Pacific Lamprey Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
50°F–64°F OBSERVED RANGE FOR HIGH SURVIVAL AND LOW OCCURRENCES OF EMBRYONIC DEVELOPMENTAL ABNORMALITIES							
Hazel Avenue							
Favorable	3 (12.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (8.0%)	0 (0.0%)
Unfavorable	3 (12.0%)	3 (12.0%)	2 (8.0%)	3 (12.0%)	3 (12.0%)	1 (4.0%)	3 (12.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)
Unfavorable	3 (12.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	2 (8.0%)	1 (4.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have both beneficial and adverse impacts on Pacific lamprey spawning and egg incubation in the lower American River due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey ammocoetes rear in the lower American River for all or part of their 3- to 7-year freshwater residence. Larvae spend a month maturing to ammocoetes before leaving spawning areas to find suitable rearing habitat, usually shallow, off-channel areas with low flow velocity where they will spend the next several years filter-feeding and maturing to juvenile stage. Once juveniles, they will begin migrating towards the ocean. Data from rotary screw trapping in the nearby Feather River suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006), although some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006) and in other river systems (Moyle 2002).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 1 compared to the No Action Alternative are a mix of increases and decreases, depending on water year type and month (Table O-25 and Table O-26). Impacts of these changes in flow on Pacific lamprey ammocoete rearing would likely be mixed, as rearing takes place over several years, so ammocoetes would likely experience both the increases and decreases in flows. Impacts might be mitigated due to ammocoetes being burrowed into sediment, but the extent to which impacts are mitigated is difficult to determine. Flow decreases in some months of critically dry years could have an adverse impact on ammocoete rearing and pose a threat to ammocoete survival. Conversely, flow increases during some months of dry water years and especially the flow increase during March and April (depending on site) of critically dry years would likely benefit ammocoete rearing for Pacific lamprey. Impacts on juvenile emigration would also likely be mixed, as flows are increased or decreased compared to the No Action Alternative depending on month and water year type. Decreases in flow during certain months of critically dry years during the winter to summer outmigration period might have an adverse impact on juvenile emigration, though overall effects would be dependent on water year type and the months that individuals spend emigrating.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 48 for Hazel Avenue and Table 50 for Watt Avenue.

Results for the analysis are summarized in Table O-117. Table O-117, as described in Section O.4.17.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific lamprey ammocoete rearing and emigration under Alternative 1, there were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-117). There were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that there would be negligible positive and negative water temperature-related effects to Pacific lamprey ammocoete rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Table O-117. Summary of Results for Water Temperature Analyses for Pacific Lamprey Ammocoete Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
72°F UPPER LIMIT FOR HIGH SURVIVAL AND LOW OCCURRENCE OF DEVELOPMENTAL ABNORMALITIES							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	1 (1.7%)	0 (0.0%)	1 (1.7%)	1 (1.7%)	2 (3.3%)	0 (0.0%)	2 (3.3%)
Unfavorable	2 (3.3%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (6.7%)	1 (1.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have negligible beneficial and adverse impacts on Pacific lamprey ammocoete rearing and emigration due to differences in water temperature.

O.4.17.5 Stanislaus River

Spawning and Egg Incubation

Hannon and Deason (2008) have documented Pacific lampreys spawning in the lower American River from early January to late May, with peak spawning typically in early April. Spawning time is presumably similar in the Stanislaus River. Eggs are laid in redds constructed in shallow water, and incubation takes several weeks. Impacts from water flows and water temperature on eggs are present February-June, likely with a peak April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows for the Stanislaus River at the mouth and below Goodwin Dam are generally greater under Alternative 1 than under the No Action Alternative across all

water year types (Table O-27). Under Alternative 1 flows at the mouth see more beneficial impacts relative to the No Action Alternative than flows at Goodwin Dam. Impacts on Pacific lamprey spawning would likely be mixed, with flow increases during most months of the spawning period (February through June) likely to have beneficial impacts on spawning. Flows decrease in March below Goodwin Dam in wet, above normal, and below normal years, which could have an adverse impact, but increases at both sites for most water year types during the peak spawning period in April and May make it likely that overall impacts on spawning would be beneficial.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities during April through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 62 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-118. Table O-118, as described in Section O.4.17.5, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities of Pacific lamprey, there was one month-water year type combination (4.0%) with favorable results and zero combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-118).

These results suggest that Alternative 1 would have negligible water temperature related effects on Pacific lamprey spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Table O-118. Summary of Results for Water Temperature Analyses for Pacific Lamprey Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
50°F–64°F OBSERVED RANGE FOR HIGH SURVIVAL AND LOW OCCURRENCES OF EMBRYONIC DEVELOPMENTAL ABNORMALITIES							
Orange Blossom Bridge							
Favorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have a minor adverse to minor beneficial impact on Pacific lamprey spawning and egg incubation, with more instances of beneficial impacts due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have a negligible impact on Pacific lamprey spawning and egg incubation in the Stanislaus River due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey ammocoetes are expected to rear in the Stanislaus River for all or part of their 3- to 7-year freshwater residence. Larvae usually spend a month in their spawning areas before becoming ammocoetes and moving to rearing habitat in shallow, off-channel areas. After several years, they become juveniles and migrate out to the ocean. Data from rotary screw trapping in the nearby Mokelumne and Tuolumne Rivers suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006). Catches of juvenile Pacific lampreys in trawl surveys of the mainstem San Joaquin River, near the mouth of the Stanislaus River at Mossdale, occurred during winter and spring. Some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows for the Stanislaus River at the mouth and below Goodwin Dam are generally greater under Alternative 1 than under the No Action Alternative across all water year types (Table O-27). Under Alternative 1 flows at the mouth see more positive change relative to the No Action Alternative than flows at Goodwin Dam. Impacts on Pacific lamprey ammocoete rearing would likely be mixed, as ammocoetes spend a period of several years upstream maturing and would therefore be present to experience the flow increases and decreases that Alternative 1 would entail. Impacts on Pacific lamprey juvenile emigration would likely be mostly beneficial, as flows are projected to increase for most months in the early winter-early summer window for the majority of emigration. Reduced flows in some water year types for January, March, and April would likely not have much of an impact on outmigration.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 63 for Orange Blossom Bridge and Table 64 for the Stanislaus River above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-119. Table O-119, as described in Section O.4.17.5, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific lamprey, there were zero and four month-water year type combinations (0.0% and 6.7%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-119). There were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 1 would have negligible water temperature related effects on Pacific lamprey ammocoete rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Table O-119. Summary of Results for Water Temperature Analyses for Pacific Lamprey Ammocoete Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
72°F UPPER LIMIT FOR HIGH SURVIVAL AND LOW OCCURRENCE OF DEVELOPMENTAL ABNORMALITIES							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above Confluence							
Favorable	4 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial to adverse impacts on Pacific lamprey ammocoete rearing and minor beneficial impacts on emigration due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have a negligible impact on Pacific lamprey ammocoete rearing and emigration in the Stanislaus River due to differences in water temperature.

O.4.17.6 San Joaquin River

Ammocoete Rearing and Emigration

Pacific lamprey larvae, once emerged, spend roughly a month in spawning areas before becoming ammocoetes and moving to rearing habitat in shallow, off-channel waters with low flow velocity, where they will spend the following several years (roughly three-seven) maturing to the juvenile stage. Once juveniles, they begin migrating towards the ocean. Midwater trawl surveys in the San Joaquin River suggest that peak ammocoete out-migration occurs in January and February (Hanni et al. 2006). Ammocoetes are vulnerable to habitat loss due to the nature of their rearing habitat.

CalSim 3 estimates for monthly flows in the San Joaquin River at Vernalis for Alternative 1 compared to the No Action Alternative indicate a mix of flow increases and decreases depending on month and water year type (Table O-29). Impacts on ammocoete rearing for Pacific lamprey would likely be mixed. Alternative 1 would possibly see a chance of minor adverse impacts on the initial part of the juvenile outmigration period due to reduced flows across almost water year types in October and November, as emigration occurs in early winter through early summer, though these decreases are before the emigration period begins in earnest. General increases in flow across water year types from December through June indicate that most impacts on juvenile emigration would likely be minorly beneficial.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on Pacific lamprey in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

<u>Summary</u>

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial and minor adverse impacts on Pacific lamprey ammocoete rearing and minor beneficial impacts on juvenile emigration in the San Joaquin River due to differences in flow. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.4.17.7 Bay-Delta

Some Pacific lamprey ammocoetes likely spend part of their extended (three to seven years) freshwater residence rearing in the Delta, particularly in the upstream, freshwater portions (California Department of Water Resources et al. 2013). Ammocoetes are present year-round in all of the regions (California Department of Water Resources et al. 2013). Data from the Fall Midwater Trawl Survey in the lower Sacramento and San Joaquin Rivers and Suisun Bay suggest that peak out-migration of Pacific lamprey through the Delta coincides with high-flow events from fall through spring (Hanni et al. 2006). Water temperature and flows affect resident ammocoetes year-round and migrating juveniles fall-spring. Duration of estuarine adult migration and holding in the San Francisco Estuary is poorly understood, but some evidence suggests they may migrate as early as the fall and throughout the spawning season until late June (Moyle et al. 2015).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows at Rio Vista under Alternative 1 would see a mix of increases and decreases compared to the No Action Alternative (Table O-22). For impacts in the southern Delta, see the San Joaquin River section above, which discusses flow at Vernalis. Impacts on Pacific lamprey ammocoete rearing are likely to be negligible, as flows at Rio Vista remain adequate even after projected decreases. Impacts on juvenile emigration and adult migration of Pacific lamprey are likely to be minorly beneficial, as flows in the summer of critically dry water year types increase compared to the No Action Alternative at Rio Vista. There are expected decreases in flow in the winter of critically dry water year types, but these flows are likely adequate for migration.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial impacts on Pacific lamprey juvenile emigration and adult migration in the summer of critically dry water year types due to differences in flow. Impacts on ammocoete rearing are expected to be negligible.

Potential Changes to Entrainment of Pacific Lamprey

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on Pacific lamprey entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for Pacific lamprey include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Whereas at the SWP Banks Pumping Plant flows no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Pacific lamprey of Alternative 1 compared to the No Action Alternative at CVP Jones Pumping Plant were similar or greater across all water year types (Table O-120 and Table O-121). At the CVP Jones Pumping Plant predicted average monthly loss was up to 17% greater for January through October of below normal water year types and as low as 1% December through January and March through August of wet water years (Table O-121). Historical loss of Pacific lamprey is infrequent; this is a driver of low values of predicted loss.

Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Pacific lamprey of Alternative 1 compared to the No Action Alternative at CVP Jones Pumping Plant were similar or greater across all water year types (Table O-120 and Table O-121).

Table O-120. Predicted Average Monthly Loss of Pacific Lamprey at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	0	0	0	0	0	0	0	0	No Fish
Above Normal	0	0	0	0	0	0	0	0	No Fish
Below Normal	0	0	0	0	0	0	0	0	No Fish
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Table O-121. Predicted Average Monthly Loss of Pacific Lamprey at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	9	9 (1%)	9 (0%)	8 (%-1)	8 (-3%)	8 (-3%)	5 (-44%)	9 (0%)	8: Dec-Jan, Mar–Aug
Above Normal	8	9 (12%)	8 (0%)	8 (0%)	7 (-7%)	7 (-7%)	3 (-62%)	8 (1%)	8: Dec-Jan, Mar–Aug
Below Normal	82	96 (17%)	81 (-1%)	82 (0%)	68 (-17%)	68 (-18%)	42 (-48%)	82 (0%)	10: Jan–Oct
Dry	42	46 (8%)	41 (-2%)	41 (-2%)	36 (-14%)	36 (-15%)	11 (-73%)	42 (-2%)	6: March–Aug
Critically Dry	93	102 (11%)	95 (2%)	103 (11%)	101 (9%)	101 (9%)	23 (-75%)	93 (0%)	10: Dec–Sep

Summary

Alternative 1 relative to the No Action Alternative is largely expected to have a minimal to an adverse impact on the entrainment of Pacific lamprey at the CVP Jones facility due to differences in exports, supported by results from the salvage density model. There is no predicted average monthly loss at the SWP Banks facility.

O.4.18 Western River Lamprey

O.4.18.1 Sacramento River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature effects on eggs may occur in February-July but are likely to occur primarily in April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River at Red Bluff Diversion Dam and below Keswick Dam for Alternative 1 compared to the No Action Alternative are a mix of increases and decreases (Table O-14 and Table O-15). Impacts on Western river lamprey spawning are likely to be somewhat mixed as well. Flow in spawning months is likely to see little change below Red Bluff Diversion Dam, outside of some water year types in June and July, which see some increases, and August, which has decreases. Flow values below Keswick Dam during spawning are largely increased compared to the No Action Alternative. August is projected to see some flow decreases below Keswick Dam, like RBDD, though this is at the very end of the spawning period and thus will not have as great of an impact as a decrease during peak spawning months. Overall, flow changes under Alternative 1 are likely to have slight beneficial to no effect on Western river lamprey spawning. Slight flow increases in spawning months below Keswick Dam could have a slight beneficial effect, as several of these increases come during peak spawning and egg incubation time in dry and critically dry years, but flows are expected to remain high enough at both locations year-round that spawning and egg incubation should not be greatly affected by either the slight increases in spawning months or the August decreases.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 301 for Keswick Dam and Table 302 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-122. Table O-122, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at both Keswick Dam and RBDD (Table O-122). There were three and zero combinations (10.0% and 0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 1 on Western river lamprey spawning and egg incubation in the Sacramento River.

Table O-122. Summary of Results for Water Temperature Analyses for Western River Lamprey Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
50°F–64°F OBSERVED RANGE OF HIGH SURVIVAL AND LOW OCCURRENCE EMBRYONIC DEVELOPMENTAL ABNORMALITIES							
Keswick Dam							
Favorable	0 (0.0%)	3 (10.0%)	3 (10.0%)	3 (10.0%)	3 (10.0%)	5 (16.7%)	1 (3.3%)
Unfavorable	3 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Western river lamprey spawning and egg incubation due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have adverse impacts on Western river lamprey spawning and egg incubation in the Sacramento River due to differences in water temperature.

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River at Red Bluff Diversion Dam and below Keswick Dam for Alternative 1 compared to the No Action Alternative are a mix of increases and decreases (Table O-14 and Table O-15). Impacts on Western river lamprey ammocoete rearing are likely to be somewhat mixed as well. Ammocoete rearing would possibly benefit from the slight increases in dry and critically dry summer months below Keswick Dam, while flow decreases in some fall months at both locations could have a slight adverse impact. Overall, beneficial impacts are possible in some summer months and adverse impacts are possible in some fall months, but flows are expected to be high enough that riverbed rearing habitat should not be threatened, and all impacts should therefore be minimal. Juvenile emigration would likely also see minimal impacts, as flows are consistently high enough that survival is unlikely to be threatened.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Western river lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Keswick Dam and Table 305 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-123. Table O-123, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results at both Keswick Dam and RBDD (Table O-123). These results suggest that there would be negligible water temperature-related effects of Alternative 1 on Western river lamprey ammocoete rearing and emigration in the Sacramento River.

Table O-123. Summary of Results for Water Temperature Analyses for Western River Lamprey Ammocoete Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
72°F UPPER LIMIT FOR HIGH SURVIVAL AND LOW OCCURRENCE OF DEVELOPMENTAL ABNORMALITIES FOR WESTERN RIVER LAMPREY							
Keswick Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Red Bluff Diversion Dam							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Western river lamprey ammocoete rearing, and negligible impacts on Western river lamprey juvenile emigration due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on Western river lamprey ammocoete rearing and emigration in the Sacramento River due to differences in water temperature.

O.4.18.2 Lower American River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature effects on eggs may occur February-July but are likely to occur primarily in April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 1 are a mix of increases and decreases compared to the No Action Alternative (Table O-25 and Table O-26). Impacts on Western river lamprey spawning are likely to be similarly mixed. Flow increases in June and in critically dry April months could be beneficial to spawning, while decreases in most water year types during July and August would likely have adverse impacts. Flows during the peak spawning period of April and May do not differ greatly compared to the No Action Alternative. Impacts during this period are mainly in critically dry years, which would see flow increases in April followed by decreases in May compared to the No Action Alternative. Overall effects on spawning are mixed, with minor beneficial and minor adverse impacts across the spawning period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in Western river lamprey during February through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 83 for Hazel Avenue and Table 84 for Watt Avenue.

Results for the analysis are summarized in Table O-124. Table O-124, as described in Section O.4.18.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in Western river lamprey spawning and egg incubation under Alternative 1, there were three and one month-water year type combinations (10.0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-124). There were three and four month-water year type combinations (10.0% and 13.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 1, there would be positive and negative water temperature-related impacts to Western river lamprey spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Table O-124. Summary of Results for Water Temperature Analyses for Western River Lamprey Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
50°F–64°F OBSERVED RANGE FOR HIGH SURVIVAL AND LOW OCCURRENCES OF EMBRYONIC DEVELOPMENTAL ABNORMALITIES							
Hazel Avenue							
Favorable	3 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (6.7%)	0 (0.0%)
Unfavorable	3 (10.0%)	4 (13.3%)	2 (6.7%)	4 (13.3%)	3 (10.0%)	1 (3.3%)	3 (10.0%)
Watt Avenue							
Favorable	1 (3.3%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	3 (10.0%)
Unfavorable	4 (13.3%)	1 (3.3%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	3 (10.0%)	1 (3.3%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor adverse to minor beneficial impacts on Western river lamprey spawning and egg incubation due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have both beneficial and adverse impacts on Western river lamprey spawning and egg incubation in the lower American River due to differences in water temperature.

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 1 are a mix of increases and decreases compared to the No Action Alternative (Table O-25 and Table O-26). Impacts on Western river lamprey ammocoete rearing are likely to be mixed as well. Flows increase and decrease depending on month and water year type, and as ammocoetes rear for several years upstream, they would be subject to the range of these fluctuations. The greatest effects would be felt during critically dry years, when flows are expected to drop to low levels in May, September, and November. Low flows in these months could have moderate adverse impacts on rearing and increase the risk of ammocoete mortality. Impacts on juvenile emigration due to flow changes from Alternative 1 are likely to be mixed too, with a range of flow increases and decreases during the outmigration period of winter through early summer. The greatest impacts would be felt during November and May of critically dry years, as low flows during these months could have moderate adverse effects on emigration, which is likely not strongly affected by the majority of other flow decreases during the emigration period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 85 for Hazel Avenue and Table 86 for Watt Avenue.

Results for the analysis are summarized in Table O-125. Table O-125, as described in Section O.4.18.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey spawning and egg incubation under Alternative 1, there were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-125). There were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that there would be negligible water temperature-related effects to Western river lamprey ammocoete rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Table O-125. Summary of Results for Water Temperature Analyses for Western River Lamprey Ammocoete Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
72°F UPPER LIMIT FOR HIGH SURVIVAL AND LOW OCCURRENCE OF DEVELOPMENTAL ABNORMALITIES							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (4.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial to moderate adverse impacts on Western river lamprey ammocoete rearing and emigration due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on Western river lamprey ammocoete rearing and emigration in the lower American River due to differences in water temperature.

O.4.18.3 Stanislaus River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific Lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature effects on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Stanislaus River below Goodwin Dam and at the mouth for Alternative 1 are generally more increased than decreased compared to the No Action Alternative (Table O-27 and Table O-28). Impacts on Western river lamprey spawning would likely be minorly beneficial. Increased flows in most water year types from March through June would likely have a beneficial impact on spawning, increasing spawning success and egg survival, especially in dry and critically dry water years when flows are at their lowest. Flow decreases below Goodwin Dam in March of wet, above normal, and below normal years could have an adverse impact on spawning, but dry and critically dry years have increased flows that would likely have a greater beneficial impact on spawning than adverse impacts during the other water year types. Overall impacts on spawning are likely to be beneficial, most notably in drier water years when flow increases could have a greater impact and could dictate the success of spawning.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in Western river lamprey during February through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 65 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-126. Table O-126, as described in Section O.4.18.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities of Western river lamprey, there were two month-water year type combination (6.7%) with favorable and unfavorable results at Orange Blossom Bridge (Table O-126).

These results suggest that Alternative 1 would have minor positive to minor negative water temperature related effects on Western river lamprey spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Table O-126. Summary of Results for Water Temperature Analyses for Western River Lamprey Spawning and Egg Incubation for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
50°F–64°F OBSERVED RANGE FOR HIGH SURVIVAL AND LOW OCCURRENCES OF EMBRYONIC DEVELOPMENTAL ABNORMALITIES							
Orange Blossom Bridge							
Favorable	2 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (6.7%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	1 (3.3%)	3 (10.0%)	1 (3.3%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor adverse to moderate beneficial impacts on Western river lamprey spawning and egg incubation due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Western river lamprey spawning and egg incubation in the Stanislaus River due to differences in water temperature.

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Stanislaus River below Goodwin Dam and at the mouth for Alternative 1 are generally increased more than decreased compared to the No Action Alternative (Table O-27 and Table O-28). Impacts on Western river lamprey ammocoete rearing are likely be to both beneficial and adverse. Increased flows during spring and summer months, especially in dry and critically dry water years, are likely to help increase ammocoete survival and success. However, flows at both locations are decreased in October across all water year types. Below Goodwin Dam, flows decrease by up to 76% in critically dry years. Decreases of this scale could have serious adverse effects on ammocoete survival and success, greatly affecting rearing. Effects of flows changes compared to the No Action Alternative on juvenile emigration would likely be minorly beneficial. Flows are generally increased from December through June, which is the primary period of emigration. Increased flows would likely provide a benefit and increase juvenile health and survival. Alternative 1 would have mixed effects on ammocoetes and juveniles, providing slight benefits most of the year while having serious adverse effects for one month each year of the multi-year rearing period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 66 for Orange Blossom Bridge and Table 67 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-127. Table O-127 as described in Section O.4.18.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Western river lamprey, there were zero and four month-water year type combinations (0.0% and 6.7%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-127). There were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 1 would have positive water temperature related effects on Western river lamprey ammocoete rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Table O-127. Summary of Results for Water Temperature Analyses for Western River Ammocoete Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
72°F UPPER LIMIT FOR HIGH SURVIVAL AND LOW OCCURRENCE OF DEVELOPMENTAL ABNORMALITIES							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above Confluence							
Favorable	4 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)	1 (1.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have moderate beneficial to substantial adverse impacts on Western river lamprey ammocoete rearing and emigration due to differences in flow. Alternative 1 relative to the No Action Alternative is expected to have beneficial impacts on Western river lamprey ammocoete rearing and emigration in the Stanislaus River due to differences in water temperature.

O.4.18.4 San Joaquin River

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 estimates of monthly flows in the San Joaquin River at Vernalis for Alternative 1 are generally increased compared to the No Action Alternative (Table O-29). Impacts on Western river lamprey ammocoete rearing are likely to be generally beneficial. Increased flows in critically dry summer months would provide the greatest benefit, providing a beneficial impacts when flows are lowest and likely increasing the survival and success of ammocoetes. Decreased flows in October and November would not benefit Western river lamprey, but flows are expected to be high enough that ammocoete rearing would likely not see an adverse impact. Effects on juvenile emigration would likely be minimal, as most flow decreases come outside the primary outmigration period.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on Western river lamprey in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible to minor beneficial impacts on Western river lamprey ammocoete rearing and emigration in the San Joaquin River due to differences in flow. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.4.18.5 Bay-Delta

The Sacramento and San Joaquin River Basins are at the southern edge of the range for Western river lamprey (Moyle et al. 2009). While their population abundance is poorly understood, they are frequently caught in the Delta Juvenile Fish Monitoring Program in the winter months through trawls at Sherwood Harbor, Mossdale, and Chipps Island (Interagency Ecological Program et al. 2022). Ammocoetes spend an unknown amount of time (likely 3-5 years) in silt-sand backwater eddies and have been documented during dredging studies in the Delta (Lamprey Technical Workgroup 2021; Moyle et al. 2015). Metamorphosis may take 9-10 months, and once complete the recently transitioned juveniles may aggregate immediately upriver from salt water and enter the ocean in late spring (Moyle et al. 2015). Adults typically start their migration back into their natal habitats in the fall (Moyle et al. 2015).

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Bay-Delta under Alternative 1 would see a mix of increases and decreases compared to the No Action Alternative (Table O-22). For impacts in the southern Delta, see the San Joaquin River section above, which discusses flow at Vernalis. Similar to Pacific lamprey, impacts of flow changes on Western river lamprey ammocoete rearing are likely to be negligible, as flows in the Sacramento River at Rio Vista remain high enough for rearing even after projected decreases. Impacts on juvenile emigration are likely to be minorly beneficial, as flows during the outmigration period in the winter are adequate for juvenile emigration and there are projected increases in critically dry water year types in the

summer. Impacts on adult migration are likely to be negligible, as flows are expected to be similar (less than a 5% difference) in the fall of critically dry water year types.

Summary

Alternative 1 relative to the No Action Alternative is expected to have minor beneficial impacts on Western river lamprey juvenile emigration in critically dry water year types and negligible impacts on adult migration due to differences in flow. Impacts on ammocoete rearing are expected to be negligible.

Potential Changes to Entrainment of Western River Lamprey

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on Western river lamprey entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation)*.

Salvage Density

Predictions from the salvage density model for Western river lamprey include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

There was no loss anticipated for any water year type for any alternative at the SWP Banks Pumping Plant. Predicted average monthly loss of Western river lamprey of Alternative 1 compared to the No Action Alternative at CVP Jones Pumping Plant were greater all water year types, except in dry water year types when no fish are expected (Table O-128 and Table O-129). At the CVP Jones Pumping Plant predicted average monthly loss was up to 20% greater for January of below normal water year types and as low as 2% February through March of critically dry water years (Table O-129). Historical loss of Western river lamprey is infrequent; this is a driver of low values of predicted loss.

Predicted average monthly loss of Western river lamprey of Alternative 1 compared to the No Action Alternative at CVP Jones Pumping Plant were greater across all water year types, except in dry water year types when no fish are expected (Table O-128 and Table O-129).

Table O-128. Predicted Average Monthly Loss of Western River Lamprey at Banks by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	0	0	0	0	0	0	0	0	No Fish
Above Normal	0	0	0	0	0	0	0	0	No Fish
Below Normal	0	0	0	0	0	0	0	0	No Fish
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Table O-129. Predicted Average Monthly Loss of Western River Lamprey at Jones by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	1	1 (6%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (2%)	1 (0%)	1: Jan
Above Normal	1	1 (15%)	1 (-1%)	1 (-1%)	1 (-1%)	1 (-1%)	1 (-35%)	1 (-2%)	1: Jan
Below Normal	5	6 (20%)	5 (-3%)	5 (-3%)	5 (-3%)	5 (-3%)	2 (-56%)	5 (-3%)	1: Jan
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	3	4 (2%)	3 (-5%)	3 (-6%)	3 (-9%)	3 (-9%)	1 (-61%)	4 (3%)	2: Feb–March

Summary

Alternative 1 relative to the No Action Alternative is largely expected to have a minimal to adverse impact on the entrainment of Western river lamprey at the CVP Jones facility due to differences in flow, supported by results from the salvage density model. There is no predicted average monthly loss at the SWP Banks facility.

O.4.19 Striped Bass

O.4.19.1 Sacramento River

Spawning and Egg Incubation

It is believed that striped bass do not spawn or rear in the Sacramento River upstream of RBDD (Tehama-Colusa Canal Authority 2008). Most spawning in the Sacramento River occurs in the lower river between Colusa and the confluence of the Sacramento and Feather Rivers (Moyle 2002). About one-half to two-thirds of adults spawn in the Sacramento River and the remainder spawn in the Delta (Leet et al. 2001). After spawning, most adult striped bass move downstream into brackish and salt water for summer and fall (Moyle 2002).

Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

Potential Changes to Striped Bass from Seasonal Operations

<u>CalSim 3 Flows</u>

During the April through June spawning and egg incubation period of striped bass, CalSim 3 estimates of mean monthly flows at Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City under Alternative 1 are generally similar (≤ ±5%) to the No Action Alternative, except in June (on average 5 to 10% higher flows) (Table O-14 through Table O-16). Because striped bass

eggs are free-floating and negatively buoyant and hatch as they drift downstream, these flow levels are likely to be adequate for spawning and egg incubation, so no adverse effects relative the No Action Alternative are expected to result and may in fact have beneficial effects in June. Therefore, Alternative 1 would likely have minimal beneficial flow effects on striped bass eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 68°F optimal water temperature range for spawning, embryo incubation and initial rearing for striped bass during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 317 for Butte City.

Results for the analysis are summarized in Table O-130. Table O-130, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 59°F to 68°F optimal water temperature range, there were five month-water year type combinations (33.3% of total combinations during the period) with favorable results at Butte City (Table O-130). There were no combinations (0%) with unfavorable results at Butte City. These results suggest that there would be positive water temperature-related impacts from Alternative 1 on striped bass spawning and egg incubation in the Sacramento River.

Table O-130. Summary of Results for Water Temperature Analyses for Striped Bass Spawning and Egg Incubation in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
59°F–68°F OPTIMAL RANGE FOR SPAWNING, EMBRYO INCUBATION, AND INITIAL REARING							
Butte City							
Favorable	5 (33.3%)	2 (13.3%)	3 (20.0%)	1 (6.7%)	2 (13.3%)	1 (6.7%)	1 (6.7%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	3 (20.0%)	1 (6.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative for CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will largely remain similar, except in June when there may be beneficial impacts. The optimal water temperature range modeling estimates indicate 33% month-water year type combinations with favorable and no combinations with unfavorable results at Butte City. Overall, these results suggest that there would be beneficial flow impacts for spawning habitat extent and beneficial water temperature-related impacts on striped bass spawning and egg incubation in the Sacramento River under Alternative 1.

Laval–Juvenile Rearing and Emigration

During this early period the embryos and larvae in the Sacramento River are carried into the Delta and Suisun Bay (Moyle 2002). YOY striped bass distribute themselves in accordance with the estuarine salinity gradient (Kimmerer 2002a; Feyrer et al. 2007), indicating that salinity is a major factor affecting their habitat use and geographic distributions. Kimmerer (2002a) found that distributions of fish species, including striped bass, substantially overlapped with the low-salinity zone. Older individuals are increasingly flexible about their distribution relative to salinity (Moyle 2002). Statistically significant correlations between indices of age-0 abundance or survival in the San Francisco Estuary and Delta have been found with Delta outflow (which can be approximated by X2, the distance in km from the Golden Gate Bridge at which bottom salinity is 2 psu) (e.g., Kimmerer et al. 2009; Mac Nally et al. 2010), with evidence for greater extent of habitat as the mechanism (Kimmerer et al. 2009). However, subsequent density-dependent survival after the first summer dampens the effects of flow on subsequent recruitment (Kimmerer et al. 2000).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

During the July through October rearing period of striped bass, CalSim 3 estimates of mean monthly flows at Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City under Alternative 1 are generally similar (≤ ±5%) to the No Action Alternative, except in August and September (on average 5 to 10% lower flows) (Table O-14 through Table O-16). Because striped bass juveniles prefer lower flows, these flow levels are likely to be adequate for rearing habitat, so no adverse effects relative the No Action Alternative are expected to result, and may in fact have beneficial effects in August and September. Therefore, Alternative 1 would likely have minimal beneficial flow effects on striped bass rearing relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F range of optimal temperatures for larvae, fry, and juvenile rearing and emigration year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 318 for Butte City.

Results for the analysis are summarized in Table O-131. Table O-131, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 61°F to 71°F optimal water temperature range for larvae, fry, and juvenile rearing and emigration, there were three month-water year type combinations (5.0% of total combinations during the period) with both favorable and unfavorable results at Butte City (Table O-131). These results suggest that there would be negligible positive and negative water temperature-related effects of Alternative 1 on striped bass larvae, fry, and juvenile rearing and emigration in the Sacramento River.

Table O-131. Summary of Results for Water Temperature Analyses for Striped Bass Larvae, Fry, and Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
61°F–71°F OPTIMAL WATER TEMPERATURE RANGE FOR LARVAE, FRY, AND JUVENILE REARING AND EMIGRATION							
Butte City							
Favorable	3 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (6.7%)	2 (3.3%)
Unfavorable	3 (5.0%)	2 (3.3%)	1 (1.7%)	2 (3.3%)	2 (3.3%)	3 (5.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative CalSim3 flow modeling and temperature modeling had some differences. The differences determined by CalSim3 modeling suggests juvenile rearing and emigration habitat extent will largely remain similar, except August and September when minimal beneficial impacts may be expected. The optimal water temperature range modeling estimates indicate 5% month-water year type combinations with favorable and unfavorable results at Butte City. Overall, these results suggest that there would be minimal beneficial flow impacts and negligible water temperature impacts on striped bass juvenile rearing and emigration habitat in the Sacramento River under Alternative 1.

O.4.19.2 Lower American River

Adults

Striped bass are present in the lower American River throughout the year, with the greatest abundance in summer (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

During the October through March non-spawning period of striped bass, CalSim 3 estimates of mean monthly flows below Nimbus Dam and at H Street under Alternative 1 are generally similar (≤ ±5%) to the No Action Alternative, except in November (on average 8% lower flows) (Table O-25 and Table O-26). Because striped bass prefer moderate flows and adjust to a wide range of flow conditions, these flow levels are likely to be generally adequate with minimal adverse impacts relative the No Action Alternative. Therefore, Alternative 1 would likely have minimal adverse flow effects on striped bass rearing relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F stress initiation value for adult striped bass year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 93 for Hazel Avenue and Table 94 for Watt Avenue.

Results for the analysis are summarized in Table O-132. Table O-132, as described in Section O.4.19.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 77°F stress initiation water temperature value for adult striped bass under Alternative 1, there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-132). There were also zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that under Alternative 1, there would be negligible water temperature-related effects to adult striped bass in the lower American River at Hazel Avenue and Watt Avenue.

Table O-132. Summary of Results for Water Temperature Analyses for Adult Striped Bass for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
77°F STRESS INITIATION WATER TEMPERATURE VALUE							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative CalSim3 flow and water temperature modeling had some differences. The differences determined by CalSim3 modeling suggests spawning habitat extent will remain similar, except five to six months out of the year with slight to beneficial and/or adverse impacts. The optimal water temperature range modeling estimates indicate there are no combinations with beneficial or adverse results at Butte City. Overall, these results suggest that there would be beneficial and adverse impacts from flow for adult habitat and negligible water temperature-related impacts to adult striped bass in the lower American River at Hazel Avenue and Watt Avenue under Alternative 1compared to the No Action Alternative.

Juvenile Rearing

Although the occurrence of spawning in the lower American River is uncertain, the river is believed to serve as a nursery area for YOY and subadult striped bass (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

During the July through October rearing period of striped bass, CalSim 3 estimates of mean monthly flows below Nimbus Dam and at H Street under Alternative 1 are generally similar (≤ ±5%) to the No Action Alternative, except in July and September (on average 20 to 22% lower

flows) (Table O-25 and Table O-26). Because striped bass juveniles prefer lower flows, these flow levels are likely to be adequate for rearing habitat, so no adverse effects relative the No Action Alternative are expected to result and may in fact have beneficial effects in July and September. Therefore, Alternative 1 would likely have minimal beneficial flow effects on striped bass rearing relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 95 for Hazel Avenue and Table 96 for Watt Avenue.

Results for the analysis are summarized in Table O-133. Table O-133, as described in Section O.4.19.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 61°F to 71°F optimal range for juvenile striped bass rearing under Alternative 1, there were five and nine month-water year type combinations (8.3% and 15.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-133). There were zero and five month-water year type combinations (0% and 8.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 1, there would be positive water temperature-related impacts to juvenile striped bass rearing in the lower American River at Hazel Avenue and Watt Avenue.

Table O-133. Summary of Results for Water Temperature Analyses for Juvenile Striped Bass Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
61°F–71°F OPTIMAL RANGE							
Hazel Avenue							
Favorable	5 (8.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (6.7%)	1 (1.7%)
Unfavorable	0 (0.0%)	1 (1.7%)	3 (5.0%)	2 (3.3%)	1 (1.7%)	0 (0.0%)	3 (5.0%)
Watt Avenue							
Favorable	9 (15.0%)	0 (0.0%)	2 (3.3%)	2 (3.3%)	0 (0.0%)	3 (5.0%)	4 (6.7%)
Unfavorable	5 (8.3%)	5 (8.3%)	4 (6.7%)	2 (3.3%)	4 (6.7%)	6 (10.0%)	3 (5.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative, CalSim3 flow and water temperature modeling show some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will remain similar, except five to six months out of the year with beneficial and/or adverse impacts. The optimal water temperature range modeling estimates indicate generally favorable month-water year type combinations at Hazel Avenue and Watt Avenue in the lower American River. Overall, these results suggest that there would be generally adverse and beneficial flow impacts and beneficial water temperature-related impacts to juvenile striped bass rearing in the lower American River at Hazel Avenue and Watt Avenue.

O.4.19.3 Stanislaus River

Spawning and Egg Incubation

Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. These adult fish were observed in all habitats (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (U.S. Fish and Wildlife Service 2002).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

During the April through June spawning and egg incubation period of striped bass, CalSim 3 estimates of mean monthly flows at Goodwin Dam and mouth of the Stanislaus River under Alternative 1 are generally greater (on average 7 to 22%) than under the No Action Alternative (Table O-27 and Table O-28). Because striped bass eggs are free-floating and negatively buoyant and hatch as they drift downstream, these flow levels are likely to be adequate for spawning and egg incubation, so no adverse effects relative the No Action Alternative are expected to result and may in fact have beneficial effects. Therefore, Alternative 1 would likely have minor beneficial flow impacts on striped bass eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 59°F to 68°F optimal range of water temperature for spawning, embryo incubation, and initial rearing of striped bass for April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 70 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-134. Table O-134, as described in Section O.4.19.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 59°F to 68°F optimal range of water temperature for spawning, embryo incubation, and initial rearing of striped bass, there was one month-water year type combination (6.7%) with favorable results and two month-water year type combinations (13.3%) with unfavorable results at Orange Blossom Bridge (Table O-134). These results suggest that Alternative 1 would have negative water-temperature related impacts on striped bass spawning, embryo incubation, and initial rearing at Orange Blossom Bridge in the Stanislaus River.

Table O-134. Summary of Results for Water Temperature Analyses for Striped Bass Spawning, Embryo Incubation and Initial Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
59°F–68°F OPTIMAL RANGE OF WATER TEMPERATURE FOR SPAWNING, EMBRYO INCUBATION AND INITIAL REARING							
Orange Blossom Bridge							
Favorable	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)
Unfavorable	2 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative, CalSim3 flow and temperature modeling show some differences. The differences determined by CalSim3 modeling suggests projected averaged flows may have beneficial impacts on spawning and egg incubation nearly the entire period. The optimal water temperature range modeling estimates indicate a 6.7% month-water year type combination with favorable results and 13.3% combinations with adverse results at Orange Blossom Bridge. Overall, these results suggest generally beneficial flow impacts and adverse water temperature impacts to striped bass spawning and egg incubation in the Stanislaus River at Goodwin Dam and the mouth under Alternative 1.

Laval–Juvenile Rearing and Emigration

Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (U.S. Fish and Wildlife Service 2002).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

During the July through October rearing period of striped bass, CalSim 3 estimates of mean monthly flows below Goodwin Dam are generally similar (≤ ±5%) to the No Action Alternative, except in October (on average 56% lower flows); mean monthly flows at the mouth of the Stanislaus River under Alternative 1 are generally higher (on average 12 to 23%) to the No Action Alternative, except in October (on average 25% lower flows) (Table O-27 and Table O-28). Because striped bass juveniles prefer lower flows, these flow levels are likely to be adequate for rearing habitat, so no adverse effects relative the No Action Alternative are expected to result and may in fact have beneficial effects in July and September. Therefore, Alternative 1 would likely have generally beneficial flow effects on striped bass rearing relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 71 for Orange Blossom Bridge and Table 72 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-135. Table O-135, as described in Section O.4.19.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing there were two and 13 month-water year type combinations (3.3% and 21.7%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-135). There were six month-water year type combinations (10.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. These results suggest that Alternative 1 would have positive and negative water temperature-related impacts on juvenile striped bass rearing in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Table O-135. Summary of Results for Water Temperature Analyses for Larval and Juvenile Striped Bass Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
61°F–71°F OPTIMAL RANGE							
Orange Blossom Bridge							
Favorable	2 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)
Unfavorable	6 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)
Above Confluence							
Favorable	13 (21.7%)	2 (3.3%)	2 (3.3%)	2 (3.3%)	2 (3.3%)	1 (1.7%)	2 (3.3%)
Unfavorable	6 (10.0%)	3 (5.0%)	4 (6.7%)	3 (5.0%)	3 (5.0%)	6 (10.0%)	4 (6.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative, CalSim3 flow and water temperature modeling show some differences. The differences determined by CalSim3 modeling suggests projected averaged flows may have noteworthy (≥ 5%) beneficial impacts between 50% to 58% of the year and adverse impacts up to 17% of the year. The optimal water temperature range modeling estimated 3.3% (Orange Blossom Bridge) and 21.7% (above the confluence with the San Joaquin River) month-water year type combinations with favorable results and 10.0% adverse combinations (both locations). Overall, these results suggest there would be generally beneficial flow impacts and adverse and beneficial water temperature-related impacts on juvenile striped bass rearing and adverse in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

O.4.19.4 San Joaquin River

Striped bass are regularly found in San Joaquin River tributaries, including in lower mainstem deep pools of the Stanislaus and Tuolumne Rivers (e.g., Anderson et al. 2007). Ainsley et al. (2013) reported that striped bass were collected at two locations between the Head of the Old River and the mouth of the Stanislaus River on the mainstem San Joaquin River in May. In the San Joaquin River outflow is balanced by tidal currents, so that embryos and larvae stay suspended in the same general area in which spawning took place. Essentially, larval bass from both rivers are most abundant where salt and fresh water meet. Thus, when they begin to feed they are concentrated in the most productive portions of the entire estuary. Larval growth and

survival rates are also highest in areas of brackish water, presumably because of reduced energy costs for osmoregulation (Moyle 2002).

Potential Changes to Striped Bass from Seasonal Operations

During the January through December in non-spawning habitat of striped bass, CalSim 3 estimates of mean monthly flows at Vernalis are generally similar (≤ ±5%) to the No Action Alternative, except in October (on average 6% lower) and July through September (on average 6 to 7% higher) (Table O-29). Because striped bass non-spawning adults prefer moderate flows, these flow levels are likely to be adequate for non-spawning habitat and should generally gave negligible effects relative the No Action Alternative, except in July through October. Therefore, Alternative 1 would likely have generally have a mix of minimal adverse and beneficial flow effects on striped bass relative to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on striped bass in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

Summary

Alternative 1 compared to the No Action Alternative CalSim 3 flow modeling differs; beneficial impacts on striped bass are be expected July through September and adverse impacts are expected in October. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.4.19.5 Bay-Delta

Striped bass use the Delta as a migratory route and for rearing and seasonal foraging. Striped bass spend the majority of their lives in salt water, returning to freshwater to spawn. Adult striped bass spend about 6 to 9 months of the year in San Francisco and San Pablo Bays (Hassler 1988). Striped bass also use deeper areas of many of the larger channels in the Delta, in addition to large embayments such as Suisun Bay.

Spawning occurs in spring, primarily in the Sacramento River between Sacramento and Colusa and in the San Joaquin River between Antioch and Venice Island (Farley 1966). Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all striped bass eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

During the January through December in non-spawning habitat of striped bass, CalSim 3 estimates of mean monthly flows at SWP and CVP exports and OMR are generally higher (on average up to 89%) to the No Action Alternative, except in November (on average lower);

estimates of mean monthly flows at Delta Outflow are generally lower on average up 39% (Table O-19 through Table O-21). Because striped bass non-spawning adults prefer moderate flows, these flow levels are likely to be adequate for non-spawning habitat and should generally have beneficial effects relative to the No Action Alternative. Therefore, Alternative 1 would likely have generally have a mix of adverse and beneficial flow effects on striped bass relative to the No Action Alternative. Differences in Delta outflow between April and June due to seasonal operations under Alternative 1 compared with the No Action Alternative may have effects on striped bass annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the striped bass.

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for striped bass indicated that the overall average abundance index for Alternative 1 would essentially be similar to the No Action Alternative across all water year types except in critically dry years (-3% to -1%, +12% in critically dry years).

Summary

Overall, under Alternative 1 compared to the No Action Alternative CalSim3 flow and Delta outflow species abundance modeling had some differences. The differences determined by CalSim3 modeling suggests mean flows may have a mix of adverse and beneficial impacts at Delta export facilities and OMR. Predictions from the Delta Outflow model for striped bass indicated that the overall average abundance index for Alternative 1 would essentially be similar to the No Action Alternative during all water year types except in critically dry years striped bass abundances may increase up to 12%. Overall, CalSim3 and Delta Outflow species abundance modeling suggest Alternative 1 would have beneficial impacts on striped bass in critically dry water years.

Potential Changes to Entrainment of Striped Bass

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on striped bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for striped bass include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative. Predicted average monthly loss of striped bass under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were similar or greater all water year types. At the SWP Banks Pumping Plant predicted average monthly loss was up to 34% greater for critically dry and below normal water year types, respectively (Table O-136 and Table O-137). At CVP Jones Pumping Plant predicted average monthly loss was up to 7% greater for above normal water years (Table O-137).

Predicted average monthly loss of striped bass under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were similar or greater during all water year types.

Table O-136. Predicted Average Monthly Loss of Striped Bass at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	27466	31026 (13%)	27934 (2%)	27937 (2%)	27906 (2%)	27874 (1%)	12136 (-56%)	27798 (1%)	12: Jan–Dec
Above Normal	24564	29500 (20%)	25047 (2%)	25032 (2%)	24742 (1%)	24731 (1%)	10264 (-58%)	24946 (2%)	12: Jan–Dec
Below Normal	30668	38292 (25%)	31938 (4%)	32296 (5%)	32314 (5%)	32258 (5%)	19197 (-37%)	31231 (2%)	12: Jan–Dec
Dry	9098	11531 (27%)	9146 (1%)	9074 (0%)	8953 (-2%)	8814 (-3%)	5709 (-37%)	8957 (-2%)	12: Jan–Dec
Critically Dry	2661	3570 (34%)	2765 (4%)	2643 (-1%)	2699 (1%)	2698 (1%)	3007 (13%)	2795 (5%)	12: Jan–Dec

Table O-137. Predicted Average Monthly Loss of Striped Bass at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	4877	4736 (-3%)	4712 (-3%)	4715 (-3%)	4655 (-5%)	4656 (-5%)	2197 (-55%)	4723 (-3%)	12: Jan–Dec
Above Normal	4588	4924 (7%)	4620 (1%)	4598 (0%)	4447 (-3%)	4429 (-3%)	1130 (-75%)	4604 (0%)	12: Jan–Dec
Below Normal	8818	9331 (6%)	8264 (-6%)	8134 (-8%)	7838 (-11%)	7873 (-11%)	2042 (-77%)	8563 (-3%)	12: Jan–Dec
Dry	11980	12272 (2%)	10538 (-12%)	10583 (-12%)	10554 (-12%)	10649 (-11%)	1748 (-85%)	10825 (-10%)	12: Jan–Dec
Critically Dry	3712	3930 (3%)	3612 (-3%)	3754 (1%)	3663 (-1%)	3633 (-2%)	843 (-77%)	3417 (-8%)	12: Jan–Dec

Summary

Overall, Alternative 1 compared to the No Action Alternative salvage density modeling results had some differences. The modeling predicted monthly loss under Alternative 1 would be similar or greater all water year types, suggesting adverse impacts from entrainment.

O.4.20 American Shad

O.4.20.1 Sacramento River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River. Migrating adults generally take 2 to 3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Keswick Dam under Alternative 1 range from about 4,000 cfs for March in critically dry years to 24,000 cfs for February of wet water years (Table O-14). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 1 cannot be determined to have adverse impacts. Differences in flows between Alternative 1 and the No Action Alternative are small in these months, but flows are slightly higher (16%) for Alternative 1 in April of critically dry water years (Table O-14). Therefore, Alternative 1 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 319 for Butte City.

Results for the analysis are summarized in Table O-138. Table O-138, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 62°F to 75°F optimal range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at Butte City (Table O-138). There was one combination (6.7%) with unfavorable results at Butte City. These results suggest that there would be negligible water temperature-related impacts from Alternative 1 on American shad spawning and larval rearing in the Sacramento River.

Table O-138. Summary of Results for Water Temperature Analyses for American Shad for Spawning and Larval Rearing in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
62°F–75°F OPTIMAL RANGE FOR SPAWNING AND LARVAL REARING							
Butte City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (13.3%)	0 (0.0%)
Unfavorable	1 (6.7%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on American shad spawning and larval rearing due to differences in flow. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation below Keswick Dam under Alternative 1 compared to the No Action Alternative are negligible on American shad spawning and larval rearing in the Sacramento River. Therefore, the differences in flow and temperature for Alternative 1 compared to the No Action Alternative are expected to have a negligible impact American shad spawning and larval rearing.

Juvenile Rearing and Emigration

In the Sacramento River, summer rearing habitat occurs in the main river from Colusa to the north Delta (Stevens et al. 1987). As the season progresses, juvenile shad move downstream and enter salt water primarily during September through November (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigrate back into Delta, CalSim 3 estimates of mean monthly flows below Keswick Dam under Alternative 1 range from about 4,200 cfs for October in critically dry years to 8,500 cfs for September of wet water years (Table O-14). Because American shad are anadromous fish that migrate great lengths to reach their spawning grounds, these flow levels are likely to be adequate for juvenile rearing and emigration, so no adverse impacts are expected to result. Differences in flows between Alternative 1 and the No Action Alternative are slightly lower (14%) for Alternative 1 in September of above normal water years (Table O-14). Therefore, Alternative 1 would likely have

negligible impacts from flow on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F range optimal range for juvenile rearing and emigration during July through November are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 320 for Butte City.

Results for the analysis are summarized in Table O-139. Table O-139, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 63°F to 77°F optimal range, there were seven month-water year type combinations (28.0% of total combinations during the period) with favorable results at Butte City (Table O-139). There was one month-water year type combination (4.0%) with unfavorable results at Butte City. These results suggest that there would be positive water temperature-related effects of Alternative 1 on American shad juvenile rearing and emigration in the Sacramento River.

Table O-139. Summary of Results for Water Temperature Analyses for American Shad for Juvenile Rearing and Emigration in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
63°F–77°F OPTIMAL RANGE FOR JUVENILE REARING AND EMIGRATION							
Butte City							
Favorable	7 (28.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	4 (16.0%)	4 (16.0%)
Unfavorable	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is expected to have negligible impacts on American shad juvenile rearing and emigration due to differences in flow. Flow for rearing and emigration is not a limiting factor for American shad. Water temperatures for larval rearing and emigration below Keswick Dam under Alternative 1 compared to the No Action Alternative are suggested to have beneficial impacts on American shad juvenile rearing and emigration in the Sacramento River. Therefore, the differences in flow and temperature for Alternative 1 compared to the No Action Alternative are expected to have some beneficial impacts on American shad spawning and larval rearing.

O.4.20.2 Lower American River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River. Migrating adults generally take two to three months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962). Adult American shad migrate into the lower American River to spawn during the late spring, typically during April through early July (California Department of Fish and Wildlife 1986).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Nimbus Dam and H street under Alternative 1 range from about 3,600 cfs for April in critically dry years to 12,000 cfs for February of wet water years (Table O-25 and Table O-26). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Differences in flows between Alternative 1 and the No Action Alternative are small in these months, but flows are much higher (149%) for Alternative 1 in April of critically dry water years (Table O-25 and Table O-26). This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected, however there is no strong evidence that shows differences in flows can be determined to have adverse effects (Stevens and Miller 1983, Stevens et al. 1987). Therefore, Alternative 1 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range for American shad spawning and larval rearing during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 97 for Hazel Avenue and Table 98 for Watt Avenue.

Results for the analysis are summarized in Table O-140. Table O-140, as described in Section O.4.20.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 62°F to 75°F optimal range for American shad spawning and larval rearing under Alternative 1, there were three and two month-water year type combinations (20.0% and 13.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-140). There were one and zero month-water combinations year type (6.7% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 1, there would be positive water temperature-related impacts on American shad spawning and larval rearing in the lower American River at Hazel Avenue and Watt Avenue.

Table O-140. Summary of Results for Water Temperature Analyses for American Shad Spawning and Larval Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
62°F–75°F OPTIMAL RANGE FOR AMERICAN SHAD SPAWNING AND LARVAL REARING							
Hazel Avenue							
Favorable	3 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (13.3%)	3 (20.0%)	2 (13.3%)
Unfavorable	1 (6.7%)	0 (0.0%)	2 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	2 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)
Unfavorable	0 (0.0%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	0 (0.0%)	1 (6.7%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is largely expected to have negligible impacts on American shad spawning and larval rearing below Nimbus Dam and at H Street due to differences in flow. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation Hazel Avenue and Watt Avenue under Alternative 1 compared to the No Action Alternative will have beneficial impacts on American shad spawning and larval rearing in the lower American River. Therefore, the differences in flow and water temperature for Alternative 1 compared to the No Action Alternative in the lower American

River are expected to have some beneficial impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

American shad rearing and emigration in the lower American River is dependent on water temperatures. August through September, but before November, are optimal months for juvenile American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Nimbus Dam and H street under Alternative 1 range from about 600 cfs for October in critically dry years to 4,000 cfs for September of wet water years (Table O-25 and Table O-26). Differences in flows between Alternative 1 and the No Action Alternative are consistently lower (22%) for Alternative 1 in September during all water year types for both sites (Table O-25 and Table O-26). Because American shad are anadromous fish that migrate great lengths to reach their spawning grounds, these flow levels are likely to be adequate for juvenile rearing and emigration, so no adverse impacts are expected. Therefore, Alternative 1 would likely have negligible impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for American shad juvenile rearing and emigration during July through November are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 99 for Hazel Avenue and Table 100 for Watt Avenue.

Results for the analysis are summarized in Table O-141. Table O-141, as described in Section O.4.20.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 63°F to 77°F optimal range for American shad spawning and larval rearing under Alternative 1, there were two and three month-water year type combinations (8.0% and 12.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-141). There were one and zero month-water year type combinations (4.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 1, there would be positive water temperature-related impacts on American shad juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Table O-141. Summary of Results for Water Temperature Analyses for American Shad Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
63°F–77°F OPTIMAL RANGE FOR AMERICAN SHAD JUVENILE REARING AND EMIGRATION							
Hazel Avenue							
Favorable	2 (8.0%)	2 (8.0%)	1 (4.0%)	1 (4.0%)	2 (8.0%)	3 (12.0%)	2 (8.0%)
Unfavorable	1 (4.0%)	1 (4.0%)	1 (4.0%)	2 (8.0%)	0 (0.0%)	1 (4.0%)	3 (12.0%)
Watt Avenue							
Favorable	3 (12.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	2 (8.0%)	3 (12.0%)	2 (8.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is largely expected to have negligible impacts on American shad juvenile rearing and emigration due to differences in flow. Flow for rearing and emigration is not a limiting factor for American shad. Water temperatures for larval rearing and emigration at Hazel Avenue and Watt Avenue under Alternative 1 compared to the No Action Alternative are suggested to have beneficial impacts on American shad juvenile rearing and emigration in the lower American River. Therefore, the differences in flow and water temperature for Alternative 1 compared to the No Action Alternative are expected to have beneficial impacts on American shad spawning and larval rearing.

O.4.20.3 Stanislaus River

Spawning and Larval Rearing

American shad migrate up the Stanislaus River to spawn in the late spring and support a sport fishery during that period. American shad have been observed on occasion from June through July at Lovers Leap (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). American shad were found primarily in the faster habitats and were observed in schools of 20 or more (U.S. Fish and Wildlife Service 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Goodwin Dam and Stanislaus River mouth under Alternative 1 range from about 230 cfs for March below Goodwin Dam in critically dry years to 2300 cfs for February at Goodwin Dam of wet water years (Table O-27 and Table O-28). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Differences in flows between Alternative 1 and the No Action Alternative are moderately higher (40%) for Alternative 1 in February of dry water years at both stations (Table O-27 and Table O-28) This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 1 cannot be determined to have adverse impacts. Therefore, Alternative 1 would likely have negligible impacts from flow on American shad spawning and larval rearing relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range for American shad spawning and larval rearing during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 73 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-142. Table O-142, as described in Section O.4.20.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 59°F to 68°F 62°F to 75°F optimal range for American shad spawning and larval rearing, there were zero month-water year type combinations (0.0%) with favorable results and two month-water year type combinations (13.3%) with unfavorable results at Orange Blossom Bridge (Table O-142). These results suggest that Alternative 1 would have negative water-temperature related impacts on American shad spawning and larval rearing at Orange Blossom Bridge in the Stanislaus River.

Table O-142. Summary of Results for Water Temperature Analyses for American Shad Spawning and Larval Rearing for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
62°F–75°F OPTIMAL RANGE FOR AMERICAN SHAD SPAWNING AND LARVAL REARING							
Orange Blossom Bridge							
Favorable	0 (0.0%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	0 (0.0%)	1 (6.7%)
Unfavorable	2 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative is largely expected to have negligible impacts on American shad spawning and larval rearing due to differences in flow. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation at Orange Blossom Bridge Dam under Alternative 1 compared to the No Action Alternative will have adverse water temperature impacts on American shad spawning and larval rearing at Orange Blossom Bridge in the Stanislaus River. Therefore, the differences in flow and temperature for Alternative 1 compared to the No Action Alternative in the lower American River are expected to have some adverse impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

American shad rearing and emigration in the Stanislaus River is dependent on water temperatures. From Orange Blossom Bridge to just above the confluence, juvenile rearing and emigration generally occur in July for American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Goodwin Dam and Stanislaus River Mouth under Alternative 1 range from about 130 cfs for October in critically dry years to 590 cfs for September below Goodwin Dam of wet water years (Table O-27 and Table O-28). Differences in flows between Alternative 1 and the No Action Alternative are severely lower (77%) for Alternative 1 in October at Goodwin Dam during critically dry years and 33% lower at Stanislaus River Mouth in October during critically dry years (Table O-27 and Table O-28). With

reduced flows at both sites, American Shad may lose rearing habitat along banks and in vegetation. Therefore, Alternative 1 would likely have some adverse flow impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for American shad juvenile rearing and emigration during July through November are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 74 for Orange Blossom Bridge and Table 75 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-143. Table O-143, as described in Section O.4.20.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 63°F to 77°F optimal range for American shad juvenile rearing and emigration there were zero and five month-water year type combinations (0.0% and 20.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-143). There were two and zero month-water year type combinations (8.0% and 0.0%, respectively) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. These results suggest that Alternative 1 would have positive water temperature-related impacts on American shad juvenile rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Table O-143. Summary of Results for Water Temperature Analyses for American Shad Juvenile Rearing and Emigration for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
63°F–77°F OPTIMAL RANGE FOR AMERICAN SHAD JUVENILE REARING AND EMIGRATION							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (8.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Above Confluence							
Favorable	5 (20.0%)	1 (4.0%)	1 (4.0%)	1 (4.0%)	1 (4.0%)	2 (8.0%)	1 (4.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Alternative 1 relative to the No Action Alternative may have adverse impacts on American shad juvenile rearing and emigration due to differences in flow, through loss of rearing habitat, however flow for rearing and emigration may not be a limiting factor for American shad. Water temperatures for larval rearing and emigration at Orange Blossom Bridge and above the confluence under Alternative 1 compared to the No Action Alternative are suggested to have beneficial water temperature impacts on American shad juvenile rearing and emigration in the Stanislaus River. Therefore, the differences in flow and temperature for Alternative 1 compared to the No Action Alternative are expected to have some adverse and beneficial impacts on American shad spawning and larval rearing.

O.4.20.4 San Joaquin River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas. Migrating adults generally take 2 to3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962). Little is known about American shad populations inhabiting the San Joaquin River. American shad may spawn in the San Joaquin River system, but their abundance is unknown.

Potential Changes to American Shad from Seasonal Operations

During the February to April adult American shad migration into the Delta, CalSim 3 estimates of mean monthly flows in the San Joaquin River at Vernalis under Alternative 1 range from about 2150 cfs for March critically dry years to 13,000 cfs for February of wet water years (Table O-29). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Differences in flows between Alternative 1 and the No Action Alternative are slightly higher (9%) for Alternative 1 in April of dry water years (Table O-29). This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 1 cannot be determined to have adverse impacts. Therefore, Alternative 1 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on American shad in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

Summary

There may be negligible impacts of seasonal operations on American shad spawning and larval rearing based on analyses of simulated flows under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows are likely to have a negligible impact on American shad juvenile rearing and non-spawning adult. Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have

a negligible impact on American shad spawning and larval rearing in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the American shad spawning and larval rearing period (Figure O-16).

Juvenile Rearing and Emigration

American shad rearing and emigration is dependent on water temperatures. Generally, juvenile rearing and emigration generally occur in July for American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

During the September to November juvenile American shad emigration back into the Delta, CalSim 3 estimates of mean monthly flows in the San Joaquin River at Vernalis under Alternative 1 range from about 800 cfs for September in critically dry years to 2,900 cfs for November in the San Joaquin River at Vernalis of wet water years (Table O-29) Differences in flows between Alternative 1 and the No Action Alternative are moderately higher (20%) for Alternative 1 in September and slightly lower (10%) in October in the San Joaquin River at Vernalis during critically dry years (Table O-29). With these flows, American shad may not be affected by Alternative 1. Therefore, Alternative 1 would likely have negligible impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on American shad in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile rearing and non-spawning adult period (Figure O-16).

<u>Summary</u>

There may be negligible impacts from seasonal operations on American shad juvenile rearing and non-spawning adults based on analyses of simulated flows under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows are likely to have a negligible impact on American shad juvenile rearing and non-spawning adult. Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impacts on American shad in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile rearing and non-spawning adult period.

O.4.20.5 Bay-Delta

American shad spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento, Feather, American, and Yuba Rivers. Some spawning also takes place in the lower San Joaquin, Mokelumne, and Stanislaus Rivers (U.S. Fish and Wildlife Service 1995). The spawning migration may begin as early as February, but most adults migrate into the Delta in March and early April (Skinner 1962). Migrating adults generally take 2 to 3 months to pass through the Sacramento–San Joaquin estuary (Painter et al. 1979).

American shad rearing and emigration in the Bay-Delta is dependent on water temperatures. August through September, but before November, are optimal months for juvenile American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

Differences in Delta outflow between February and June due to seasonal operations under Alternative 1 compared with the No Action Alternative may have effects on American shad annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the American shad.

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for American shad indicated that the overall abundance index for Alternative 1 would be the lowest when compared to the No Action Alternative across all water year types (-6% to +1%, -3% overall).

Summary

There may be adverse impacts from seasonal operations on American shad spawning and larval rearing based on analyses of simulated flows under Alternative 1 in comparison to the No Action Alternative. American shad abundance index for Alternative 1 in the Bay-Delta, based on the Delta Outflow model, would be the lowest compared to the No Action Alternative across all water year types.

Potential Changes to Entrainment of American Shad

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on American shad entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for American shad include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of American shad under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were similar or greater during all water year types. At the SWP Banks Pumping Plant predicted average monthly loss was similar for all water year types (Table O-144 and Table O-145). At CVP Jones Pumping Plant predicted average monthly loss was generally similar except during above normal and critically dry water year types when loss increased up to 5% and 13%, respectively (Table O-145).

Predicted average monthly loss of American shad under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were similar or greater all water year types.

Table O-144. Predicted Average Monthly Loss of American Shad at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	28119	32338 (2%)	28595 (2%)	28582 (2%)	28601 (2%)	28596 (2%)	12597 (-55%)	28358 (1%)	12: Jan–Dec
Above Normal	25652	31252 (2%)	26255 (2%)	26216 (2%)	26180 (2%)	26139 (2%)	10783 (-58%)	26032 (1%)	12: Jan–Dec
Below Normal	19297	22915 (3%)	19841 (3%)	19372 (0%)	19946 (3%)	20020 (4%)	11822 (-39%)	19577 (1%)	12: Jan–Dec
Dry	7802	9935 (-1%)	7727 (-1%)	7643 (-2%)	8173 (5%)	8107 (4%)	6367 (-18%)	7482 (-4%)	12: Jan–Dec
Critically Dry	1575	2026 (-2%)	1551 (-2%)	1475 (-6%)	1438 (-9%)	1437 (-9%)	1534 (-3%)	1539 (-2%)	12: Jan–Dec

Table O-145. Predicted Average Monthly Loss of American Shad at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	19220	18593 (-3%)	18490 (-4%)	18511 (-4%)	18423 (-4%)	18426 (-4%)	7479 (-61%)	18414 (-4%)	12: Jan–Dec
Above Normal	17968	18779 (5%)	18286 (2%)	18154 (1%)	17759 (-1%)	17671 (-2%)	3751 (-79%)	18073 (1%)	12: Jan–Dec
Below Normal	5910	5691 (-4%)	5800 (-2%)	5733 (-3%)	5685 (-4%)	5711 (-3%)	2164 (-63%)	5885 (0%)	12: Jan–Dec
Dry	6856	6875 (0%)	6492 (-5%)	6484 (-5%)	6499 (-5%)	6580 (-4%)	1857 (-73%)	6572 (-4%)	12: Jan–Dec
Critically Dry	490	554 (13%)	486 (-1%)	498 (1%)	506 (3%)	511 (4%)	219 (-55%)	505 (3%)	12: Jan–Dec

Summary

There may be adverse impacts on American shad entrainment based on analyses of simulated exports under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, entrainment increased at Jones Pumping Plant during above normal and critically dry water year types, while entrainment at Banks Pumping Plant stayed similar to the No Action Alternative during all water year type.

O.4.21 Threadfin Shad

O.4.21.1 Sacramento River

Spawning for threadfin shad takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Threadfin shad are occasionally caught at the Red Bluff Diversion Dam RST in the Sacramento River, and occur year-round (Voss 2024).

Potential Changes to Threadfin Shad from Seasonal Operations

CalSim 3 Flows

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 1 are likely adequate for threadfin shad and impacts are likely negligible.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal spawning range during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 321 for Butte City.

Results for the analysis are summarized in Table O-146. Table O-146, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 63°F to 77°F optimal range, there were four month-water year type combinations (16.0% of total combinations during the period) with favorable conditions at Butte City (Table O-146). There were seven month-water year type combinations (28.0%) with unfavorable conditions at Butte City. These results suggest that there would be both positive and negative water temperature-related impacts from Alternative 1 on threadfin shad spawning in the Sacramento River.

Table O-146. Summary of Results for Water Temperature Analyses for Threadfin Shad for Spawning in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
63°F–77°F OPTIMAL SPAWNING RANGE							
Butte City							
Favorable	4 (16.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (16.0%)	2 (8.0%)
Unfavorable	7 (28.0%)	1 (4.0%)	0 (0.0%)	1 (4.0%)	3 (12.0%)	3 (12.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be beneficial and adverse impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows are expected to have negligible impacts on threadfin shad. Temperature analysis suggests both beneficial and adverse impacts from Alternative 1 on threadfin shad spawning in the Sacramento River.

O.4.21.2 Lower American River

Spawning for threadfin shad takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. Threadfin shad are occasionally captured as part of the non-salmonid bi-catch in the RSTs in the lower American River (Pacific States Marine Fisheries Commission 2014).

Potential Changes to Threadfin Shad from Seasonal Operations

CalSim 3 Flows

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 1 are likely adequate for threadfin shad and impacts are likely negligible.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for threadfin shad adult spawning during April through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 101 for Hazel Avenue and Table 102 for Watt Avenue.

Results for the analysis are summarized in Table O-147. Table O-147, as described in Section O.4.21.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 63°F to 77°F optimal range for threadfin shad spawning under Alternative 1, there were one and three month-water year type combinations (4.0% and 12.0%, respectively) with favorable conditions at Hazel Avenue and Watt Avenue, respectively (Table O-147). There were zero month-water year type combinations (0.0%) with unfavorable conditions at both Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 1, there would be positive water temperature-related impacts to threadfin shad spawning in the lower American River at Hazel Avenue and Watt Avenue.

Table O-147. Summary of Results for Water Temperature Analyses for Threadfin Shad Adult Spawning for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
63°F–77°F OPTIMAL RANGE FOR THREADFIN SHAD SPAWNING							
Hazel Avenue							
Favorable	1 (4.0%)	2 (8.0%)	1 (4.0%)	1 (4.0%)	2 (8.0%)	2 (8.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	0 (0.0%)
Watt Avenue							
Favorable	3 (12.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	1 (4.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be beneficial impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows are expected to have negligible impacts on threadfin shad. Temperature analysis suggests there would be beneficial water temperature-related impacts on threadfin shad spawning in the lower American River.

O.4.21.3 Stanislaus River

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Threadfin shad are occasionally captured in the Caswell RST in the lower Stanislaus River (Bradbury and Hickey 2019).

Potential Changes to Threadfin Shad from Seasonal Operations

CalSim 3 Flows

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 1 are likely adequate for threadfin shad and impacts are likely negligible.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for threadfin shad adult spawning during April through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 76 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-148. Table O-148, as described in Section O.4.21.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 63°F to 77°F optimal range for threadfin shad adult spawning, there were zero month-water year type combinations (0.0%) with favorable results and two month-water year type combinations (8.0%) with unfavorable results at Orange Blossom Bridge (Table O-148). These results suggest that Alternative 1 would have negligible negative water-temperature related impacts on threadfin shad spawning in the Stanislaus River at Orange Blossom Bridge.

Table O-148. Summary of Results for Water Temperature Analyses for Threadfin Shad Adult Spawning for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
63°F–77°F OPTIMAL RANGE FOR THREADFIN SHAD SPAWNING							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	2 (8.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

There may be negative impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows expected to have negligible impacts on threadfin shad. Temperature analysis suggests there would be adverse water temperature-related impacts on threadfin shad spawning in the Stanislaus River.

O.4.21.4 San Joaquin River

Threadfin shad spawning takes place April through August, peaking in June and July. The embryos hatch in 3 to 6 days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Juveniles can form dense schools and while they are typically abundant in freshwater, they may also be found in varying salinities throughout the estuary. Threadfin shad are fast-growing but short-lived, with an average lifespan of two years.

Potential Changes to Threadfin Shad from Seasonal Operations

Flows under Alternative 1 are likely adequate for threadfin shad and impacts are likely negligible.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on threadfin shad in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, changes in flows are expected to have negligible impacts on threadfin shad. Under Alternative 1, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout year in the San Joaquin River at Vernalis.

O.4.21.5 Bay-Delta

Potential Changes to Threadfin Shad from Seasonal Operations

Flows under Alternative 1 are likely adequate for threadfin shad and impacts are likely negligible.

Summary

There may be negligible impacts from seasonal operations on threadfin shad under Alternative 1 in comparison to the No Action Alternative.

Potential Changes to Entrainment of Threadfin Shad

Differences in exports under Alternative 1 compared with the No Action Alternative may have impacts on threadfin shad entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for threadfin shad include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of threadfin shad under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant was greater during all water year types and CVP Jones Pumping Plant increased or decreased during most water year types. At the SWP Banks Pumping Plant predicted average monthly loss increased up to 14% on critically dry water years (Table O-149 and Table O-150). At CVP Jones Pumping Plant predicted average monthly loss was increased up to 6% and 16% during above normal and critically dry water years, respectively; loss decreased up to 11% during below normal water years (Table O-150).

Predicted average monthly loss of threadfin shad under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant was greater all water year types and CVP Jones Pumping Plant increased or decreased most water year types.

Table O-149. Predicted Average Monthly Loss of Threadfin Shad at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	41839	44601 (7%)	42588 (2%)	42555 (2%)	42610 (2%)	42621 (2%)	17716 (-58%)	42525 (2%)	12: Jan–Dec
Above Normal	39789	44347 (11%)	40830 (3%)	40797 (3%)	40867 (3%)	40807 (3%)	14935 (-62%)	40717 (2%)	12: Jan–Dec
Below Normal	106556	119703 (12%)	110223 (3%)	108141 (1%)	109406 (3%)	110041 (3%)	56345 (-47%)	109688 (3%)	12: Jan–Dec
Dry	58604	62190 (6%)	56557 (-3%)	55229 (-6%)	62353 (6%)	63065 (8%)	53373 (-9%)	57683 (-2%)	12: Jan–Dec
Critically Dry	13184	15043 (14%)	13015 (-1%)	13069 (-1%)	15904 (21%)	16089 (22%)	29973 (127%)	12992 (-1%)	12: Jan–Dec

Table O-150. Predicted Average Monthly Loss of Threadfin Shad at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	59159	57640 (-3%)	57175 (-3%)	57213 (-3%)	56909 (-4%)	56982 (-4%)	26698 (-55%)	57138 (-3%)	12: Jan–Dec
Above Normal	54639	57968 (6%)	55112 (1%)	54782 (0%)	53725 (-2%)	53624 (-2%)	13767 (-75%)	54730 (0%)	12: Jan–Dec
Below Normal	86362	77243 (-11%)	84300 (-2%)	82941 (-4%)	81857 (-5%)	82356 (-5%)	18684 (-78%)	85997 (0%)	12: Jan–Dec
Dry	173859	178173 (2%)	164113 (-6%)	165038 (-5%)	165297 (-5%)	166976 (-4%)	53598 (-69%)	166012 (-5%)	12: Jan–Dec
Critically Dry	29574	34246 (16%)	27793 (-6%)	32529 (10%)	31141 (5%)	30992 (5%)	7362 (-75%)	28247 (-4%)	12: Jan–Dec

Summary

There may be beneficial and adverse entrainment impacts on threadfin shad juvenile rearing and non-spawning adults based on analyses of simulated exports under Alternative 1 in comparison to the No Action Alternative. Under Alternative 1, entrainment increased at Banks across all water year types, while entrainment at Jones increased and decreased depending on the water year type.

O.4.22 Black Basses

O.4.22.1 Three Micropterus spp.

Three *Micropterus* spp. constitute the group of black basses in California, and include largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species). All three species are introduced but have recreational value in California.

Largemouth Bass

Largemouth bass first spawn during their second or third spring at about 7 inches in length. Spawning is limited to freshwater (Moyle 2002). The males begin building nests when the water temperature reaches about 60°F (15.6°C). Spawning takes place from April through June, at temperatures up to 75°F (23.9°C).

Smallmouth Bass

Smallmouth bass reach maturity in their third or fourth spring, at which point they move into shallower water. Spawning begins in May and can continue into June or July (Moyle 2002). Spawning has been observed at temperatures ranging from 13°C to 26°C (55.4°F to 78.8°F), with optimal water temperatures ranging from 16°C to 18°C (60.8°F to 64.4°F) (Wang et al. 2010).

Spotted Bass

Maturity is reached in the second or third year and spawning occurs in freshwater when temperatures reach 15°C to 18°C (59°F to 64.4°F), continuing until temperatures reach 22°C to 23°C (71.6°F to 73.4°F) in early June. Males move to shallow water in March and early April, where they construct nests 40 to 80 cm (31.5 inches) in diameter, generally in shallow areas less than or equal to 6 m deep (University of California, Agriculture and Natural Resources 2019b; Wang et al. 2010).

O.4.22.2 Sacramento River

Spawning

Spawning occurs in freshwater for all three taxa. This means all spawning occurs upstream of the brackish estuary. See details in Section O.4.22.1 above for spawning timing of each species.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

Alternative 1 compared to the No Action Alternative CalSim3 mean monthly flows at Keswick Dam, Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that a minor (≤ 5%) increase or decrease is estimated in most months except June (higher),; this suggests habitat under Alternative 1 will largely remain similar to under the No Action Alternative (Table O-14 through Table O-17).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 323 for Butte City. Full results of the analysis assessing the percent of months with water temperature outside the 55°F to 70°F optimal range for smallmouth bass spawning during May through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 325 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 331 for Butte City.

Results for the three analyses are summarized in Table O-151. Table O-151, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-151). For the 55°F to 70°F optimal range for smallmouth bass spawning, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Hamilton City. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Butte City. These results suggest that there would be negligible water temperature-related effects of Alternative 1 on black bass spawning in the Sacramento River.

Table O-151. Summary of Results for Water Temperature Analyses for Black Basses Spawning in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
52.7°F–84.2°F OBSERVED RANGE FOR LARGEMOUTH BASS SPAWNING							
Butte City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
55°F–70°F OPTIMAL RANGE FOR SMALLMOUTH BASS SPAWNING							
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	0 (0.0%)
58.1°F–73.4°F OBSERVED RANGE FOR SPOTTED BASS SPAWNING							
Butte City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, for Alternative 1 compared to the No Action Alternative, CalSim3 flow and temperature modeling show some differences. The differences determined by CalSim3 modeling suggests spawning habitat extent will largely remain similar, except June when there may be beneficial impacts. The optimal water temperature range modeling estimates indicate neither favorable nor adverse impacts under Alternative 1 compared to the No Action Alternative. Overall, these results suggest there would be minor to slight beneficial flow impacts for spawning habitat and negligible water temperature-related impacts on largemouth, smallmouth, and spotted bass spawning and egg incubation in the Sacramento River under Alternative 1 compared to the No Action Alternative.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters and may be found from the tributaries of the Sacramento to the brackish estuary. As all three taxa require large quantities of food, they are likely to be more concentrated in areas with plentiful food and instream cover.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

For Alternative 1 compared to the No Action Alternative, CalSim3 mean monthly flows at Keswick Dam, Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that a minor (≤ 5%) increase and/or decrease is estimated in most months except June (higher), August (lower, except at Keswick Dam), September (lower, except at Keswick Dam), November (lower, at Hamilton City only) and at Keswick Dam; this suggests habitat under Alternative 1 will largely remain similar to under the No Action Alternative (Table O-14 through Table O-17).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 324 at Butte City. Full results of the analysis assessing the percent of months with water temperature above the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 327 for the Sacramento River at Hamilton. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for non-spawning adult smallmouth bass growth year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 320 for the Sacramento River at Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 332 for the Sacramento River at Butte City.

Results for the four analyses are summarized in Table O-152. Table O-152, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-152). For the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass, there were no month-water year type combinations (0%) with favorable results and three combinations (20.0%) with unfavorable results at Hamilton City. For the 77°F to 80°F optimal range for non-spawning adult smallmouth bass growth, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Hamilton City. For the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass, there was 1 month-water year type combinations (6.7%) with favorable results and no combinations (0%) with unfavorable results at Butte City. These results suggest that there would be negative water temperature-related effects of Alternative 1 on black bass non-spawning adults in the Sacramento River.

Table O-152. Summary of Results for Water Temperature Analyses for Black Bass Non-spawning Adults in the Sacramento River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
77°F–86°F OPTIMAL RANGE FOR NON-SPAWNING ADULT LARGEMOUTH BASS GROWTH							
Butte City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
66°F LOWER END OF OBSERVED SUMMER-TIME RANGE FOR NON-SPAWNING ADULT SMALLMOUTH BASS							
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (13.3%)	1 (6.7%)
Unfavorable	3 (20.0%)	2 (13.3%)	3 (20.0%)	2 (13.3%)	2 (13.3%)	2 (13.3%)	1 (6.7%)
77°F–80°F OPTIMAL RANGE FOR NON-SPAWNING ADULT SMALLMOUTH BASS GROWTH							
Hamilton City							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
75°F–87°F PREFERRED SUMMER-TIME RANGE FOR NON-SPAWNING ADULT SPOTTED BASS							
Butte City							
Favorable	1 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, for Alternative 1 compared to the No Action Alternative, CalSim3 flow and temperature modeling showed some differences. The differences determined by CalSim3 modeling suggests spawning habitat extent will largely remain similar, except 3 to 4 months of a given year when slight adverse impacts on largemouth, smallmouth, and spotted bass may be anticipated. The optimal summer water temperature range modeling estimates were neither beneficial nor adverse compared to the No Action Alternative at Butte and Hamilton cities on largemouth bass. The optimal summer water temperature range modeling estimates indicate 3(20.0%) beneficial month-water year type combinations for smallmouth bass at Hamilton City. The optimal summer water temperature range modeling estimates indicate one (6.7%) adverse combination for spotted

bass at Butte City. Overall, these results suggest that there would be minor to slight adverse flow for largemouth, smallmouth, and spotted bass; water temperature impacts were negligible on non-spawning adult largemouth bass, moderately adverse on smallmouth bass, and slightly adverse on spotted bass in the Sacramento River under Alternative 1.

O.4.22.3 Lower American River

Spawning

Spawning for all three taxa occurs in cooler, shallow waters. See details in Section O.4.22.1 above for spawning timing for each species.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

For Alternative 1 compared to the No Action Alternative, CalSim3 mean monthly flows below Nimbus Dam and at H Street indicate that moderate increases (up to 17%) or slight decreases (up to 11%) are estimated March through July (Table O-25 and Table O-26). Below Nimbus Dam, slight (up to 11%) decreases and moderate (up to 16%) increase are expected in July and June, respectively. At H street slight (up to 11%) decreases and moderate (up to 17%) increase are expected in July and June, respectively. These differences suggest habitat will experience a mix of adverse and beneficial effects during summer and fall months under Alternative 1.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 105 for Hazel Avenue and Table 106 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 55°F to 70°F optimal range for smallmouth bass spawning during May through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 109 for Hazel Avenue and Table 110 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 115 for Hazel Avenue and Table 116 for Watt Avenue.

Results for the three analyses are summarized in Table O-153. Table O-153 as described in Section O.4.22.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-153). There were zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 55°F to 70°F optimal range for smallmouth bass spawning, there were zero and two month-water year type combinations (0.0% and 13.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and one month-water

year type combinations (0.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and one month-water year type combinations (0.0% and 6.7%, respectively) with unfavorable water temperature-related results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be positive water temperature-related effects of Alternative 1 on black bass spawning in the lower American River.

Table O-153. Summary of Results for Water Temperature Analyses for Black Basses Spawning in the lower American River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
52.7°F–84.2°F OBSERVED RANGE FOR LARGEMOUTH BASS SPAWNING							
Hazel Avenue							
Favorable	1 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (13.3%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	1 (6.7%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
55°F–70°F OPTIMAL RANGE FOR SMALLMOUTH BASS SPAWNING							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	2 (13.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (6.7%)	1 (6.7%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	4 (26.7%)	2 (13.3%)
58.1°F–73.4°F OBSERVED RANGE FOR SPOTTED BASS SPAWNING							
Hazel Avenue							
Favorable	1 (6.7%)	1 (6.7%)	0 (0.0%)	1 (6.7%)	3 (20.0%)	4 (26.7%)	2 (13.3%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	1 (6.7%)	2 (13.3%)	0 (0.0%)	2 (13.3%)	2 (13.3%)	5 (33.3%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative, CalSim3 flow and temperature modeling showed some differences. The differences determined by CalSim3 modeling suggests spawning habitat extent will remain similar, except up to three months with slight to moderate favorable or adverse impacts on largemouth, smallmouth, and spotted bass. The optimal water temperature range modeling estimates indicate one (6.7%) month-water year type beneficial combination for largemouth bass at Hazel Avenue. The optimal water temperature range modeling estimates indicate 2 (13.3%) beneficial and 1 (6.7%) adverse combinations for smallmouth bass at Watt Avenue. The optimal water temperature range modeling estimates indicate one (6.7%) beneficial and adverse combinations for spotted bass at Hazel Avenue and Watt Avenue. Overall, these results suggest there would be generally slight beneficial flow impacts on largemouth, smallmouth, and spotted bass spawning habitat; water temperature-related impacts would be slightly beneficial on largemouth and smallmouth bass and negligible on spotted bass at the lower American River under Alternative 1.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters and may be found from the tributaries of the Sacramento to the brackish estuary. As all three taxa require large quantities of food, they are likely to be more concentrated in areas with plentiful food and instream cover.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

For Alternative 1 compared to the No Action Alternative, CalSim3 mean monthly flows below Nimbus Dam and at H Street indicate that minor (≤ 5%) increase and/or decrease is estimated nearly half of the months (Table O-25 and Table O-26). Below Nimbus Dam, slight (≤ 11% in July and November) and moderate (20% in September) decreases are expected an average 3 months out of year; slight (6%) and moderate (16%) increases are expected in June and June, respectively. At H street, slight (≤ 11% in July, August, and November) and moderate (22% in September) decreases are expected an average 4 months out of year; slight (6%) and moderate (17%) increases are expected in June and June, respectively. These differences suggest habitat will experience a mix of adverse and beneficial effects during summer and fall months under Alternative 1.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for growth for largemouth bass during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 107 for Hazel Avenue and Table 108 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 66°F water temperature lower end of observed

summer-time range of non-spawning adult smallmouth bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 111 for Hazel Avenue and Table 112 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for growth in smallmouth bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 113 for Hazel Avenue and 114 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 75°F to 87°F preferred summer-time range for spotted bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 117 for Hazel Avenue and Table 118 for Watt Avenue.

Results for the four analyses are summarized in Table O-154. Table O-154, as described in Section O.4.22.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue (Table O-154). There were also zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there was one month-water year type combinations (6.7%) with favorable results at both Hazel Avenue and Watt Avenue. There were three and one month-water year type combinations (20.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were zero month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that there would be negative effects of Alternative 1 on black bass non-spawning adults in the lower American River.

Table O-154. Summary of Results for Water Temperature Analyses for Non-spawning Black Basses in the Lower American River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
77°F–86°F OPTIMAL RANGE FOR GROWTH FOR LARGEMOUTH BASS							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
66°F LOWER END OF OBSERVED SUMMER-TIME RANGE FOR SMALLMOUTH BASS							
Hazel Avenue							
Favorable	1 (6.7%)	1 (6.7%)	1 (6.7%)	3 (20.0%)	2 (13.3%)	0 (0.0%)	1 (6.7%)
Unfavorable	3 (20.0%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	3 (20.0%)	1 (6.7%)	2 (13.3%)
Watt Avenue							
Favorable	1 (6.7%)	0 (0.0%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	3 (20.0%)	1 (6.7%)
Unfavorable	1 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	1 (6.7%)
77°F–80°F OPTIMAL RANGE FOR GROWTH IN SMALLMOUTH BASS							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
75°F–87°F PREFERRED SUMMER-TIME RANGE FOR SPOTTED BASS							
Hazel Avenue							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Watt Avenue							
Favorable	0 (0.0%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	1 (6.7%)	2 (13.3%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative CalSim3 flow and temperature modeling had some differences. The differences determined by CalSim3 simulated averaged water year type flows suggests spawning habitat extent will remain similar, but will have generally beneficial impacts on largemouth, smallmouth, and spotted bass. The optimal water temperature range modeling estimates indicate neither beneficial nor adverse impacts on largemouth bass at the lower American River. The optimal water temperature range modeling estimates indicate one (6.7%) month-water year type combinations with beneficial results at both Hazel Avenue and Watt Avenue while also having three (20.0%, Hazel Avenue) and one (6.7%, Watt Avenue) combinations with adverse conditions for the 66°F water temperature lower end summer-time range of smallmouth bass. The optimal water temperature range modeling estimates for spotted bass are neither beneficial nor adverse at the lower American River. Overall, these results suggest there would be generally slight beneficial flow impacts on largemouth, smallmouth, and spotted bass; water temperature impacts on non-spawning adult largemouth and spotted bass would be negligible, and on smallmouth bass would be slightly adverse in the lower American River.

O.4.22.4 Stanislaus River

Spawning

Spawning for all three taxa occurs in cooler, shallow waters. See details in Section O.4.22.1 above for spawning timing for each species. The Stanislaus River supports spawning for largemouth bass and spotted bass.

Potential Changes to Largemouth and Spotted Bass from Seasonal Operations

CalSim 3 Flows

For Alternative 1 compared to the No Action Alternative, CalSim3 mean monthly flows differences are expected to be minor (≤ 5%) to moderate (≤ 23%) increases and minor (≤ 5%) decreases at Goodwin Dam and mouth of the Stanislaus River (Table O-27 and Table O-28). At Goodwin Dam, moderate (up to 29%) increases are expected April through June. At the mouth, moderate (up to23%) increases are expected March through July. These results suggest flows may be anticipated to have generally beneficial effects on largemouth, and spotted bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 78 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 82 for Orange Blossom Bridge.

Results for the two analyses are summarized in Table O-155. Table O-155 as described in Section O.4.22.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there was one month-water year type combinations (6.7%) with favorable and unfavorable results at Orange Blossom Bridge (Table O-155). For the 58.1°F to 73.4°F observed range for spotted bass spawning, there was one month-water year type combinations (6.7%) with favorable results and three combinations (20%) with unfavorable results at Orange Blossom Bridge. These results suggest that there would be negative effects of Alternative 1 on spawning black basses spawning in the Stanislaus River.

Table O-155. Summary of Results for Water Temperature Analyses for Black Basses Spawning in the Stanislaus River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
52.7°F–84.2°F OBSERVED RANGE FOR LARGEMOUTH BASS SPAWNING							
Orange Blossom Bridge							
Favorable	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	1 (6.7%)	0 (0.0%)	1 (6.7%)
Unfavorable	1 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	0 (0.0%)
58.1°F–73.4°F OBSERVED RANGE FOR SPOTTED BASS SPAWNING							
Orange Blossom Bridge							
Favorable	1 (6.7%)	2 (13.3%)	2 (13.3%)	2 (13.3%)	2 (13.3%)	1 (6.7%)	2 (13.3%)
Unfavorable	3 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative CalSim3 flow and temperature modeling had some differences. The differences determined by CalSim3 modeling suggests flows may generally have beneficial impacts on largemouth, and spotted bass. The optimal water temperature range modeling estimates indicate one (6.7%) combinations with beneficial and adverse conditions for largemouth at Orange Blossom Bridge. The optimal water temperature range modeling estimates indicate one month-water year type combinations (6.7%) with beneficial and three (20.0%) combinations with adverse conditions for spotted bass at

Orange Blossom Bridge. Overall, these results suggest that generally beneficial flow impacts largemouth bass and spotted bass; water temperature-related impacts on largemouth bass spawning are negligible and slightly adverse on spotted bass in the Stanislaus River under Alternative 1.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters. However, they require large quantities of food; they are likely to remain in slower moving waters of the stream or move vertically within the reservoirs to accommodate preferences.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

For Alternative 1 compared to the No Action Alternative, CalSim3 mean monthly flows fluctuates between minor (≤ 3%) to moderate (≤ 29%) increases and minor (≤ 3%) to substantial (≤ 56%) decreases are estimated at Goodwin Dam and mouth of the Stanislaus River; increases above 5% in averaged flow are expected nearly half of the months (Table O-27 and Table O-28). At Goodwin Dam, slight (≤ 11%) to moderate (≤29%) increases are expected an average of six months and a substantial (56%) decrease in October; the remaining five months are projected increases and decreases are minor (≤ 5%). At the mouth, slight (≤ 13%) to moderate (≤ 23%, June and July) increases are expected an average of seven months and a slight (11%, November) to moderate (25%, October) decrease in October; the remaining three months, increases and decreases are minor (≤ 3%). These results suggest flows may be anticipated to have generally beneficial effects on largemouth, smallmouth, and spotted bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for growth for largemouth bass during year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 79 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass during June through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 80 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for growth in smallmouth bass during year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 81 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 75°F to 87°F preferred summer-time range for spotted bass during June through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 83 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-156. Table O-156 as described in Section O.4.22.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 1 for the 77°F to 86°F optimal range for growth for largemouth bass, there were 0 month-water year type combinations (0.0% with favorable and unfavorable results at Orange Blossom Road (Table O-156). For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there were zero month-water year type combinations (0.0% with favorable and unfavorable results at Orange Blossom Road. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were 0 month-water year type combinations (0.0% with favorable and unfavorable results at Orange Blossom Road For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero month-water year type combinations (0.0% with favorable and unfavorable results at Orange Blossom Road.

These results suggest that there would be negligible effects of Alternative 1 on black bass non-spawning adults in the Stanislaus River at Orange Blossom Bridge.

Table O-156. Summary of Results for Water Temperature Analyses for Non-spawning Black Basses in the Stanislaus River for Each Alternative, Presented as the Number of (percent of total) Month-Water Year Type Combinations Within the Period with Favorable and Unfavorable Results

Value/ Range	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
77°F–86°F OPTIMAL RANGE FOR GROWTH FOR LARGEMOUTH BASS							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
66°F LOWER END OF OBSERVED SUMMER-TIME RANGE FOR SMALLMOUTH BASS							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
77°F–80°F OPTIMAL RANGE FOR GROWTH IN SMALLMOUTH BASS							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
75°F–87°F PREFERRED SUMMER-TIME RANGE FOR SPOTTED BASS							
Orange Blossom Bridge							
Favorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unfavorable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

"Favorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% lower than that of the No Action Alternative (NAA). "Unfavorable" is defined as the frequency of exceedance above a temperature value or occurrence outside a temperature range under the alternative was >10% higher than that of the NAA.

Summary

Overall, under Alternative 1 compared to the No Action Alternative, CalSim3 flow and temperature modeling showed some differences. The differences determined by CalSim3 modeling suggests flows may generally have beneficial impacts on largemouth, smallmouth, and spotted bass. The optimal water temperature range modeling estimates were neither beneficial nor adverse on largemouth, smallmouth, and spotted bass. Overall, these results suggest generally beneficial flow and similar water temperature-related impacts on non-spawning on largemouth, smallmouth, and spotted bass in the Stanislaus River under Alternative 1 compared to the No Action Alternative.

O.4.22.5 San Joaquin River

Spawning occurs in freshwater for all three taxa. This means all spawning occurs upstream of the brackish estuary. Non-spawning adults are generally more tolerant of various water quality parameters and may be found from the tributaries of the San Joaquin to the brackish estuary. As all three taxa require large quantities of food, they are more likely to be concentrated in areas with plentiful food and instream cover.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

Alternative 1 compared to the No Action Alternative CalSim3 mean monthly flows vary between minor (≤ 5%) to slight (≤ 7%) increases and minor (≤ 2%) to slight (≤ 6%) decreases at Vernalis; minor increases and decreases are expected nearly 67% of the months (Table O-29). Slight increases are expected on average in July through September (7%, 7%, and 6%, respectively) and decreases (6%) in October. These results suggest flows may be anticipated to have generally similar to beneficial effects on largemouth, smallmouth, and spotted bass under Alternative 1 compared to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 1 compared to the No Action Alternative are likely to have a negligible impact on black basses in the San Joaquin River. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-16).

Summary

For Alternative 1 compared to the No Action Alternative, CalSim3 mean monthly flows differs; beneficial impacts on largemouth, smallmouth, and spotted bass may be expected July through September and adverse impacts in October. Under Alternative 1, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.4.22.6 Bay-Delta

Non-spawning adults are present year-round predominantly in the brackish water interface where food is abundant. Larvae and juveniles are likely to remain upstream of the brackish water interface.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

For Alternative 1 compared to the No Action Alternative, CalSim3 mean monthly flows fluctuates between minor (1%) to substantial (≤ 89%) increases and minor (≤ 5%) to substantial (≤ 39%) decreases are estimated in the Bay-Delta; increases and/or decreases at/or above 5% in averaged flows are expected between 67% to 83% of the months (Table O-19 through Table O-21). At SWP and CVP exports, slight (15%) to substantial (54%) flow increases are expected an average of 9 months and a minor (5%) decrease in November; the remaining two months (July and August) have minor (1%) projected increases and decreases, respectively. At the confluence of Old and Middle River in the Delta, slight (15%) to substantial (89%) flow increases are expected an average of nine months and a minor (6%) decrease in November; in July and August averaged flows are similar to the No Action Alternative (0% and -1%, respectively). At Delta outflow, slight (≤ 10%) to substantial (≤39%) decreases are expected an average of 7 months and a slight (10%) increase in June; the remaining 4 months are projected to have minor (≤ 4%) decreases. These results suggest effects of Alternative 1 on largemouth, smallmouth, and spotted bass may be generally beneficial.

Summary

For Alternative 1 compared to the No Action Alternative, CalSim3 mean monthly flows differs; beneficial impacts on largemouth, smallmouth, and spotted bass may be expected during most months of the year, with November having a minor adverse impact and June and July having a negligible impact on black bass.

Potential Changes to Entrainment of Largemouth Bass

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on largemouth bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for largemouth bass include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of largemouth bass under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were similar or greater all water year types. At the SWP Banks Pumping Plant predicted average monthly loss was up to 31% greater for below normal water years (Table O-157 and Table O-158). At CVP Jones Pumping Plant predicted average monthly loss was up 11% greater for above normal water years (Table O-158).

Predicted average monthly loss of largemouth bass under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were similar or greater all water year types.

Table O-157. Predicted Average Monthly Loss of Largemouth Bass at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	1676	1831 (9%)	1713 (2%)	1712 (2%)	1716 (2%)	1715 (2%)	853 (-49%)	1702 (2%)	12: Jan–Dec
Above Normal	1524	1742 (14%)	1544 (1%)	1545 (1%)	1531 (0%)	1529 (0%)	619 (-59%)	1542 (1%)	12: Jan–Dec
Below Normal	1346	1768 (31%)	1614 (20%)	1626 (21%)	1614 (20%)	1618 (20%)	784 (-42%)	1590 (18%)	12: Jan–Dec
Dry	1020	1199 (17%)	1054 (3%)	1040 (2%)	1064 (4%)	1061 (4%)	774 (-24%)	1055 (3%)	12: Jan–Dec
Critically Dry	776	954 (23%)	735 (-5%)	757 (-2%)	1621 (109%)	1655 (113%)	2439 (214%)	761 (-2%)	12: Jan–Dec

Table O-158. Predicted Average Monthly Loss of Largemouth Bass at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	3913	3822 (-2%)	3754 (-4%)	3757 (-4%)	3720 (-5%)	3725 (-5%)	1873 (-52%)	3755 (-4%)	12: Jan–Dec
Above Normal	3534	3919 (11%)	3478 (-2%)	3469 (-2%)	3411 (-3%)	3403 (-4%)	808 (-77%)	3473 (-2%)	12: Jan–Dec
Below Normal	5801	6143 (6%)	5368 (-7%)	5248 (-10%)	5194 (-10%)	5223 (-10%)	1073 (-82%)	5560 (-4%)	12: Jan–Dec
Dry	7843	8065 (3%)	6923 (-12%)	6951 (-11%)	6937 (-12%)	7001 (-11%)	1192 (-85%)	7112 (-9%)	12: Jan–Dec
Critically Dry	4006	4294 (7%)	3803 (-5%)	4007 (0%)	3880 (-3%)	3842 (-4%)	980 (-75%)	3639 (-9%)	12: Jan–Dec

Potential Changes to Entrainment of Smallmouth Bass

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on smallmouth bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for smallmouth bass include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of smallmouth bass of Alternative 1 compared to the No Action Alternative at SWP Banks Pumping Plant was similar in all water year types, except in dry water years when loss would increase and critically dry water year types when no fish are expected; loss at CVP Jones Pumping Plant loss would increase on below normal and critically dry water year types, all other water year types have no anticipated loss. At the SWP Banks Pumping Plant predicted average monthly loss increased up to 33% in October of dry water years and was similar to the No Action Alternative all other water years loss is expected (Table O-159 and Table O-160). At the CVP Jones Pumping Plant predicted average monthly loss increased up to 12% and 14% January through March and May of below normal water years and February of critically dry water years, respectively (Table O-160). Historic loss of smallmouth bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Predicted average monthly loss of smallmouth bass of Alternative 1 compared to the No Action Alternative at SWP Banks Pumping Plant was similar all water year types, except in dry water years when loss would increase and critically dry water year types when no fish are expected; loss at CVP Jones Pumping Plant loss would increase on below normal and critically dry water year types, all other water year types have no anticipated loss.

Table O-159. Predicted average monthly loss Smallmouth Bass at Banks by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	2	3 (1%)	2 (1%)	2 (1%)	2 (1%)	2 (1%)	1 (-49%)	2 (1%)	3: Dec–Feb
Above Normal	2	3 (2%)	2 (2%)	2 (1%)	2 (1%)	2 (-1%)	1 (-21%)	2 (8%)	3: Dec–Feb
Below Normal	3	6 (-1%)	3 (-1%)	3 (-5%)	3 (-5%)	3 (-2%)	4 (7%)	4 (3%)	2: March, Oct
Dry	6	8 (33%)	6 (-5%)	6 (-5%)	6 (-1%)	7 (3%)	7 (12%)	6 (-4%)	1: October
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Table O-160. Predicted Average Monthly Loss of Smallmouth Bass at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	0	0	0	0	0	0	0	0	No Fish
Above Normal	0	0	0	0	0	0	0	0	No Fish
Below Normal	3	3 (12%)	3 (1%)	3 (-1%)	2 (-10%)	2 (-12%)	1 (-64%)	3 (3%)	4: Jan–March, May
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	1	1 (14%)	1 (-2%)	1 (1%)	1 (-1%)	1 (-1%)	0 (-55%)	1 (7%)	1: February

Potential Changes to Entrainment of Spotted Bass

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on spotted bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for spotted bass include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of spotted bass of Alternative 1 compared to the No Action Alternative at SWP Banks Pumping Plant increased below normal water years and no fish are expected during all other water year types; at CVP Jones Pumping Plant loss increased or decreased most water year types, except wet and critically dry water year types when it would be similar. At the SWP Banks Pumping Plant predicted average monthly loss increased up to 98% in March of below normal water years (Table O-161 and Table O-162). At the CVP Jones Pumping Plant predicted average monthly loss increased up to 5% in November, December, and February of above normal water year types and 9% in March, April, and December below normal water years; loss decreased up to 8% in November of dry water years (Table O-162). Historical loss of spotted bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Predicted average monthly loss of spotted bass of Alternative 1 compared to the No Action Alternative at SWP Banks Pumping Plant increased below normal water years and no fish are expected all other water year types; at CVP Jones Pumping Plant loss increased or decreased most water year types, except wet and critically dry water year types when it would be similar.

Table O-161. Predicted Average Monthly Loss of Spotted Bass at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	0	0	0	0	0	0	0	0	No Fish
Above Normal	0	0	0	0	0	0	0	0	No Fish
Below Normal	2	3 (98%)	2 (-1%)	1 (-6%)	1 (-29%)	1 (-27%)	1 (-11%)	2 (-2%)	1: March
Dry	0	0	0	0	0	0	0	0	No Fish
Critically Dry	0	0	0	0	0	0	0	0	No Fish

Table O-162. Predicted Average Monthly Loss of Spotted Bass at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	2	2 (1%)	2 (2%)	2 (2%)	2 (2%)	2 (2%)	2 (-6%)	2 (1%)	3: Nov–Dec, Feb
Above Normal	2	2 (5%)	2 (2%)	2 (3%)	2 (3%)	2 (3%)	1 (-24%)	2 (3%)	3: Nov–Dec, Feb
Below Normal	2	3 (9%)	2 (1%)	2 (3%)	2 (-12%)	2 (-13%)	1 (-52%)	2 (0%)	3: March–April, Dec
Dry	7	6 (-8%)	7 (1%)	7 (1%)	7 (0%)	7 (2%)	4 (-35%)	7 (1%)	1: Nov
Critically Dry	1	1 (2%)	1 (-10%)	1 (-7%)	1 (-11%)	1 (-12%)	0 (-68%)	1 (-8%)	2: Jan, Aug

Summary

Overall, for Alternative 1 compared to the No Action Alternative, salvage density modeling had some differences. The salvage density modeling predicted monthly loss under Alternative 1 are similar or slightly to largely greater for largemouth bass for nearly all water year types. The salvage density modeling predicted monthly loss under Alternative 1 are similar or slightly to largely greater for smallmouth bass for nearly all water year types. The salvage density modeling predicted monthly loss under Alternative 1 are similar or slightly to largely greater for spotted bass for nearly all water year types, except in November of dry water year types when a slight decrease in loss is expected compared to the No Action Alternative.

Overall, under Alternative 1 compared to the No Action Alternative, CalSim3 flow modeling and salvage density modeling had some fluctuations. The fluctuations determined by CalSim3 modeling suggests projected averaged flows may have beneficial impacts 75% of the months at two Delta locations and unfavorable impacts 58% of the months at one location. The salvage density modeling predicted monthly loss under Alternative 1 are similar or slightly to largely greater for black bass for nearly all water year types; the only exception was for spotted bass in November of dry water year types when a slight decrease in loss is expected compared to the No Action Alternative. Overall, these results suggest that generally favorable flow impacts on black bass and noteworthy loss increases at SWP and CVP delta facilities from entrainment under Alternative 1.

O.4.23 Starry Flounder

O.4.23.1 Bay-Delta

Adult starry flounder primarily inhabit coastal marine waters (Orcutt 1950; Haertel and Osterberg 1967; Bottom et al. 1984; Hieb and Baxter 1993). Distribution of age-0 juveniles within the San Francisco Estuary and Delta is primarily in Suisun Bay and San Pablo Bay, with lower abundance in the west Delta (Baxter et al. 1999). Starry flounder older than age 1 (age-1+ fish) occur principally in San Pablo Bay, Suisun Bay, and Central Bay (Baxter et al. 1999).

Starry flounder can tolerate a wide range of salinities. In the Sacramento and San Joaquin Rivers, starry flounder have been observed in salinities as low as 0.02–0.06 ppt (i.e., essentially fresh water) (Orcutt 1950). Age-0 and age-1+ starry flounder are a common species in estuarine habitats along the West Coast (see Orcutt 1950; Pearson 1989; Emmett et al. 1991; Baxter et al. 1999; Kimmerer 2002b).

Spawning occurs primarily during the winter months of December and January (Orcutt 1950). By age-2 many starry flounder are nearing reproductive maturity and have migrated to ocean habitats adjacent to their natal estuaries. Adults may move seasonally into shallow coastal waters to spawn, perhaps in proximity to estuaries to take advantage of estuarine circulation which would advect fertilized eggs near the bottom into nursery areas.

Potential Changes to Starry Flounder from Seasonal Operations

Differences in Delta outflow between March and June due to seasonal operations under Alternative 1 compared with the No Action Alternative may have effects on starry flounder annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the starry flounder.

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for starry flounder indicated that the overall average abundance index for Alternative 1 would be the lowest when compared to the No Action Alternative in all water year types except for critically dry years. Abundance varies across other year types (-7% to -4%) but is higher in critically dry years (+14%). Overall mean abundance is -3% when combining all water year types compared to the No Action Alternative.

Summary

Alternative 1 relative to the No Action Alternative is expected to have possible minimal adverse impacts on species abundance for starry flounder in all water year types except for critically dry years due to differences in flow, which would likely result in minimal beneficial impacts on species abundance.

Potential Changes to Entrainment of Starry Flounder

Differences in exports under Alternative 1 compared with the No Action Alternative may have effects on starry flounder entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for starry flounder include mean monthly total exports. Table O-19 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 1 and the No Action Alternative.

Predicted average monthly loss of starry flounder under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant was similar or greater in all water year types. At the SWP Banks Pumping Plant, predicted average monthly loss increased in all water year types; the increase ranged from 29% in October of critically dry water years to 71% in March, April, May, July, August, and November of dry water years (Table O-163 and Table O-164). At CVP Jones Pumping Plant predicted average monthly loss was generally similar except during June through October of above normal water years and January and September of critically dry water year types when loss increased up to 14% and 19%, respectively (Table O-164). Historical loss of starry flounder at both facilities is infrequent, and this is a driver of low values of predicted loss.

Predicted average monthly loss of starry flounder under Alternative 1 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant was similar or greater in all water year types.

Table O-163. Predicted Average Monthly Loss of Starry Flounder at Banks by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	8	11 (30%)	9 (15%)	9 (15%)	9 (14%)	9 (13%)	4 (-46%)	9 (14%)	8: Dec–July
Above Normal	5	9 (60%)	6 (18%)	6 (18%)	6 (7%)	6 (6%)	3 (-36%)	6 (18%)	8: Dec–July
Below Normal	21	31 (45%)	25 (15%)	25 (18%)	25 (16%)	25 (15%)	16 (-24%)	24 (12%)	7: Feb–Aug
Dry	3	4 (71%)	4 (49%)	4 (49%)	3 (23%)	3 (22%)	3 (3%)	4 (51%)	6: March–May, July–Aug, Nov
Critically Dry	1	1 (29%)	1 (-3%)	1 (-10%)	1 (-10%)	1 (-3%)	1 (38%)	1 (-2%)	1: October

Table O-164. Predicted Average Monthly Loss of Starry Flounder at Jones by Water Year Type for All Months With Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	3	3 (0%)	3 (-4%)	3 (-4%)	3 (-5%)	3 (-5%)	1 (-55%)	3 (-4%)	5: June–Oct
Above Normal	2	3 (14%)	2 (-3%)	2 (-3%)	2 (-4%)	2 (-4%)	1 (-77%)	2 (-3%)	5: June–Oct
Below Normal	5	5 (4%)	5 (-2%)	5 (-2%)	4 (-11%)	4 (-12%)	1 (-76%)	5 (0%)	6: March–Aug
Dry	5	5 (3%)	5 (0%)	5 (0%)	4 (-5%)	4 (-5%)	2 (-64%)	5 (0%)	2: May, Nov
Critically Dry	2	2 (19%)	2 (-8%)	2 (1%)	2 (5%)	2 (4%)	1 (-53%)	2 (0%)	2: Jan, Sep

Summary

Alternative 1 relative to the No Action Alternative is expected to have adverse impacts on starry flounder entrainment at Delta Fish Collection Facilities due to differences in flow. The predicted average monthly loss of starry flounder at both Banks and Jones pumping plants was similar or greater across all water year types. The SWP Banks pumping plant predicted a greater increase in average monthly loss than CVP Jones across all water year types.

O.4.24 Coastal Pelagic Species

O.4.24.1 Potential Changes to Northern Anchovy and Pacific Herring from Seasonal Operations

Northern anchovy and Pacific herring could be subject to operational effects of the Proposed Action as it pertains to Delta outflow and its effect on the salinity field. However, the effects on salinity would be small relative to the salinity tolerance of Coastal Pelagic Species EFH such as Northern Anchovy (Baxter et al. 1999). Kimmerer et al. (2009) showed for Northern Anchovy that neither indices of habitat extent nor indices of abundance were related to X2, an index of Delta outflow and its effects.

Kimmerer (2009) found Pacific herring abundance indices were not associated with flow. However, Pacific herring do utilize the San Francisco Bay Estuary as spawning and rearing habitat (Pak et al. 2023; Grimaldo et al. 2020; Watters et al. 2004). Grimaldo et al. (2020) found Pacific herring larvae presence and abundance was lower in landward regions (e.g. Suisun Bay) during a high outflow year, likely due to either increased advection from high flows or reduced net landward movement via gravitational circulation. Juvenile herring abundance in Suisun Bay in the spring is associated with saltier conditions that allow their range to expand landward (Pak et al. 2023).

O.4.24.2 Potential Changes to Entrainment of Northern Anchovy and Pacific Herring

There are no expected impacts to entrainment of Northern anchovy due to operations since the distribution in the San Francisco Estuary has shifted towards higher salinities (> 20) since the introduction of the invasive clam, *Potamocorbula amurensis* (Kimmerer 2006). Impacts to entrainment of Pacific herring are potentially adverse in drier water year types depending on severity but are likely to be rare. Historical salvage of Pacific herring has only occurred a few times since 2000, primarily in 2014, a critically dry year (during the months of March and April), fish were also salvaged in 2019 and 2020 in much lower numbers (CDFW 2024c).

O.4.25 Southern Oregon/Northern California Coast Coho Salmon ESU

O.4.25.1 Trinity River

Spawning and Egg/Alevin Incubation

Most coho salmon spawning in the mainstem Trinity River occurs in November and December between Lewiston Dam and the North Fork Trinity River (Section O.1.2.5.1, Coho salmon, Southern Oregon/Northern California Coast ESU). Coho salmon eggs and alevins in the Trinity and Klamath River Basins may be present in the gravel from November to mid-May (Leidy and Leidy 1984), so effects of flow and water temperature on coho salmon eggs and alevins may occur during this period.

Potential Changes to Coho Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 as flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would have variable effects on the availability or suitability of spawning and egg/alevin incubation habitat for coho salmon relative to the No Action Alternative. Under Alternative 1, like the No Action Alternative, the variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

In December when coho salmon are spawning in the Trinity River, modeled monthly average flow would increase substantially (by more than 5%) in wet water years from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1 (Table O-12). The December flow increase would increase the WUA of coho salmon spawning habitat in the reach from Dutch Creek to North Fork Trinity River but would decrease coho salmon spawning WUA in downstream reaches (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The effect of the December flow increase on spawning suitability in the reach from Lewiston to Dutch Creek is uncertain because WUA in this reach has not been quantified for flows greater than 800 cfs (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The relationships between seasonal operations and WUA (i.e., habitat availability and suitability) derived from the Trinity River Flow Evaluation (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999) are assumed to provide generally applicable characterizations of flow-related effects in the Trinity River. However, the observed and predicted WUA for coho salmon from U.S. Fish and Wildlife Service and the Hoopa Valley Tribe (1999) is based on data collected prior to the large-scale channel and floodplain rehabilitation that has occurred under the TRRP. Evidence indicates that the contemporary effects of flow on salmonid WUA are now more spatially variable as a result of localized changes in channel geometry following TRRP restoration actions. Relationships between flow and WUA in the Trinity River are known to vary spatially due to the influence of remnant anthropogenic riparian berms on channel confinement and incision and the associated relationship between flow and relevant habitat suitability parameters such as depth and velocity (Goodman et al. 2018; Cooper-Hertel et al. 2022). Hydrodynamic habitat modeling by Goodman et al. (2018) showed that flow increases in unconfined channel segments in the Trinity River provide greater increases in Chinook salmon redd suitability and less risk of redd superimposition than the same flow increases in confined channel segments. Chinook salmon rearing habitat capacity in the Trinity River has been shown to be similarly affected (Cooper-Hertel et al. 2022). These studies did not specifically assess flow-related effects on coho salmon habitat suitability, but the response is assumed to be similar for coho salmon because their habitat requirements are similar to Chinook salmon. Where channel restoration has removed remnant riparian berms and reduced legacy channel confinement and incision, a stronger positive relationship between flow and salmonid habitat suitability, particularly for flows of approximately 300–1,200 cfs, can be expected than in areas of greater channel confinement. The monthly average flows in the Trinity River below Lewiston during the coho salmon egg/alevin incubation period would be too low to cause redd scour, and flow increases under Alternative 1 would therefore have no effect on the risk of redd scour relative to the No Action Alternative.

The probability of redd scour in the primary coho salmon spawning reaches of the Trinity River is predicted to be less than 1% at flows up to 5,000 cfs (Gaeuman et al. 2023).

Modeled monthly average flows in February of above normal water years would increase substantially (more than 5%) from 1,194 cfs under the No Action Alternative to 1,475 cfs Alternative 1 (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In March of below normal water years, modeled monthly average flows would decrease substantially (more than 5%) from 427 cfs under the No Action Alternative to 349 cfs under Alternative 1. The February and March flow changes would occur during the coho salmon egg/alevin incubation period. Although WUA for egg/alevin incubation is not available for the Trinity River, the changes in modeled monthly average flows in February and March under Alternative 1 would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative, especially in areas with a confined channel where relatively minor changes in flow have little influence on water depth or velocity, and no effects on egg/alevin incubation suitability are expected.

Compared with the No Action Alternative, the modeled December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the upper water temperature objective of 56°F to protect spawning coho salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11). The flow reduction in March of below normal water years would increase the modeled monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative (Figure O-17). However, this change would be unlikely to result in any exceedance of the 56°F water temperature objective in the reach from Lewiston Dam to North Fork Trinity River (Asarian et al. 2023) and no effects on spawning or incubating coho salmon are expected. Like the No Action Alternative, seasonal flow releases under Alternative 1 are also expected to maintain a relatively low risk of disease outbreaks for coho salmon by maintaining minimum flows and relatively cool water temperatures.

Compared with the No Action Alternative, the increased monthly average flows in December and February and the reduced monthly average flow in March under Alternative 1 would likely have variable impacts on the availability and suitability of coho salmon spawning and incubation habitat in the Trinity River. Overall, the impacts in the reaches most heavily used by spawning coho salmon would likely be negligible or slightly beneficial, but there is uncertainty due to the variable impacts of channel geometry on habitat suitability.

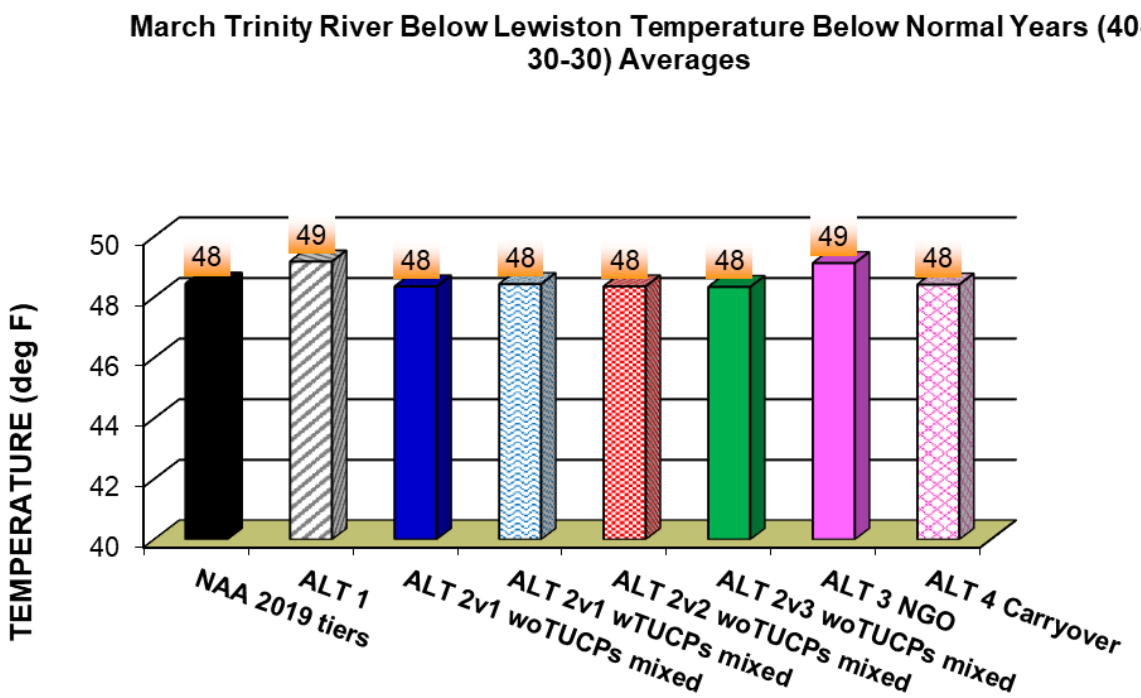


Figure O-17. Modeled Average March Water Temperatures in the Trinity River below Lewiston in March of Below Normal Water Years Under Each Alternative

Juvenile Rearing and Emigration

Naturally spawned juvenile coho salmon in the Trinity River emerge from the gravel and begin rearing in winter and early spring, with the first captures of young-of-year (age-0) coho salmon typically occurring in early March (U.S. Fish and Wildlife Service 2023, unpublished; Yurok Tribe 2023, unpublished). Fry, juvenile, and subyearling coho salmon rearing in the Trinity River strongly prefer areas of slow water velocity and habitat with cover from woody material, overhanging vegetation, and clusters of aquatic vegetation (Hampton 1988, 1997; Chase et al. 2009; Pinnix et al. 2019). During high flows, young coho salmon use floodplains and other off-channel habitats (Chase et al. 2009). Rearing occurs year-round, typically over a period of 12–15 months, and the effects of flow and water temperature on rearing coho salmon therefore occur throughout the year. Most Trinity River coho salmon outmigrate to the ocean as yearling smolts between January and July (Harris et al. 2016; Petros et al. 2015; Petros et al. 2017).

Potential Changes to Coho Salmon Juvenile Rearing and Emigration from Seasonal Operations

Minor differences in Trinity River flows between Alternative 1 and the No Action Alternative would occur in December–March of below normal and wetter water years, with both negative and positive effects on the availability of suitable juvenile rearing and emigration habitat for coho salmon. In all other months and water year types, there would be little or no difference in monthly average flow between Alternative 1 and the No Action Alternative, and no effects on coho salmon are expected.

Modeled monthly average flow in December of wet water years would increase from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1 (Table O-12) and may result in minor decreases in observed and predicted WUA for juvenile coho salmon that would vary by reach (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Potential reductions in WUA for juvenile coho salmon would occur from Lewiston Dam to Dutch Creek and from North Fork Trinity to South Fork Trinity (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the modeled monthly average flows would increase under Alternative 1 (1,475 cfs) compared with the No Action Alternative (1,194 cfs) with similar effects on WUA for juvenile coho salmon in the same two reaches. In March of below normal water years, the decrease in modeled monthly average flow from 427 cfs under the No Action Alternative to 349 cfs under Alternative 1 would increase the amount of observed and predicted WUA for coho salmon fry and juveniles in all reaches of the mainstem Trinity River (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999), with potential benefits to rearing and emigrating coho salmon. These changes in WUA for coho salmon fry and juveniles may have minor, short-term effects on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the 12–15 month rearing period and in some reaches of the Trinity River.

Compared with the No Action Alternative, the December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the 59°F water temperature objective for emigrating juvenile coho salmon recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in December and February would remain below the 59°F objective under a wide range of flow scenarios (Asarian et al. 2023), and there would be no change in the temperature suitability for rearing or emigrating coho salmon under Alternative 1 relative to the No Action Alternative. The flow reduction in March of below normal water years would increase modeled monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative (Figure O-17), but this change would be unlikely to result in any exceedance of the 59°F water temperature objective at Weitchpec (Asarian et al. 2023), and no effects on rearing or emigrating coho salmon are expected. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 1 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the coho salmon juvenile rearing and emigration period at downstream locations in some water year types under Alternative 1, water temperatures and the potential effects on coho salmon would not differ from the No Action Alternative.

Compared with the No Action Alternative, the increased monthly average flows in December and February and the reduced monthly average flow in March under Alternative 1 would cause only negligible changes in factors affecting the availability or suitability of coho salmon rearing and emigration habitat.

Adult Upstream Migration and Holding

From August to January, coho salmon return from the ocean through the Klamath River Estuary to the Trinity River, moving upstream toward spawning habitat. Based on recent weir counts, the date of peak abundance of upstream-migrating coho salmon in the Trinity River ranges from late September to mid-November (Kier et al. 2018, 2019, 2020, 2021, 2022). After completing their upstream migration, mature coho salmon may hold for days, weeks, or sometimes months before spawning. Because most spawning occurs in November and December, the effects of flow and water temperature on migrating and holding coho salmon would primarily occur from August through December.

Potential Changes to Coho Salmon Adult Upstream Migration and Holding from Seasonal Operations

Under Alternative 1, seasonal operations in the Trinity River are expected to provide similar or better habitat conditions for coho salmon upstream migration and holding than the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish including coho salmon. During the primary coho salmon upstream migration and holding period there would be no differences modeled monthly average in flow between the two alternatives in August–October, a negligible difference in November, and a substantial increase in December of wet water years.

Modeled monthly average flows from August to December when most adult coho salmon are migrating and holding would be equal to or greater than 300 cfs in all water year types to provide suitable depth for upstream passage, access to cover, and holding habitat to support pre-spawning coho salmon. Throughout this period, modeled monthly average flows under Alternative 1 would be equal to or slightly greater than flows under the No Action Alternative except for a 1 cfs average decrease in December of above normal water years (Table O-12). Although WUA for adult coho salmon upstream migration and holding is not available for the Trinity River, the modeled flow increase in December of wet water years from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1 may slightly increase suitability for migrating and holding adults by increasing water depth in some areas and increasing the volume of some holding pools.

Modeled monthly average flows in August and September, when adult coho salmon begin migrating upstream from the ocean and water temperatures are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 1 as under the No Action Alternative. Under both alternatives, modeled August and September flows of 760 cfs in wet water years and 863 cfs in all other water year types would maintain suitable water temperatures for adult upstream migration (60°F in August and early September and 56°F in late September; Table O-11). During the late September to mid-November peak adult migration period, the monthly average flows under Alternative 1 would also be the same as under the No Action Alternative and would help maintain suitable water temperatures for migration. In December of wet water years, the increased monthly average flows would help maintain suitable water temperatures for adult upstream migration and holding. Like the No Action Alternative, seasonal flow releases under Alternative 1 are expected to maintain a low risk of disease outbreaks for coho salmon by maintaining minimum flows and relatively cool water temperatures.

Compared with the No Action Alternative, seasonal operations under Alternative 1 would likely have no impact or may provide minor benefits to migrating and holding coho salmon in the Trinity River.

O.4.26 Upper Klamath-Trinity River Spring-run Chinook Salmon ESU

O.4.26.1 Trinity River

Spawning and Egg/Alevin Incubation

Most spring-run Chinook salmon in the Trinity River spawn from late September to mid-November, with a peak in October (Gough et al. 2021a,b). At optimal intragravel temperatures (41–55°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another four to six weeks (Healey 1991, Moyle 2002). In the Trinity River, spring-run Chinook salmon incubation and emergence typically occurs through February (Leidy and Leidy 1984). The effects of flow and water temperature on spring-run Chinook salmon spawning and egg/alevin incubation may therefore occur from approximately mid-September through February.

Potential Changes to Spring-run Chinook Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 to flows under the No Action Alternative. Monthly flow differences, most less than 5%, in December–February of below normal and wetter water year types would have minor and potentially beneficial effects on the availability or suitability of spawning and egg/alevin incubation habitat for spring-run Chinook salmon relative to the No Action Alternative. Under Alternative 1, like the No Action Alternative, the variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

During the late September to mid-November spawning period there would be no difference in modeled monthly average flows between Alternative 1 and the No Action Alternative (Table O-12). Average flows from September through February when spring-run Chinook salmon egg/alevin incubation occurs would be equal to or greater than 300 cfs in all water year types, and substantially greater in the wettest water years in some months, to provide suitable conditions for incubation and emergence. In December when spring-run Chinook salmon eggs and alevins are incubating in the Trinity River, modeled monthly average flow would increase substantially (by more than 5%) in wet water years from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1. Later in the incubation period, modeled monthly average flows in February of above normal water years would increase substantially (more than 5%) from 1,194 cfs under the No Action Alternative to 1,475 cfs under Alternative 1. Although WUA for egg/alevin incubation is not available for the Trinity River, the increased December and February average flows are not expected to reduce suitability for incubating Chinook salmon eggs/alevins, and the December flow increase may reduce risk of redd superimposition by later-spawning fall-run Chinook salmon and coho salmon. In all reaches of the Trinity River, the effects of flow changes on spawning and incubation suitability are likely to vary spatially with channel confinement and incision (Goodman et al. 2018). Where the channel is naturally

unconfined and not overly incised and where channel restoration has removed remnant riparian berms and reduced legacy channel confinement and incision, a stronger positive relationship between flow and salmonid habitat suitability, particularly for flows of approximately 300–1,200 cfs, can be expected than in areas of greater channel confinement (see Section O.4.24.1.1 for a detailed discussion). This is mainly a result of increasing habitat area, which also provides more space for redds and reduces the risk of redd superimposition by later-spawning salmonids.

The monthly average flows in the Trinity River below Lewiston during the spring-run Chinook salmon egg/alevin incubation period would be too low to cause redd scour, and modeled monthly average flow increases under Alternative 1 would therefore have no effect on the risk of redd scour relative to the No Action Alternative. The probability of redd scour in the primary salmon spawning reaches of the Trinity River is predicted to be less than 1% at flows up to 5,000 cfs (Gaeuman et al. 2023). In March of below normal water years, the modeled monthly average flow decrease would occur after the spring-run Chinook salmon incubation period and would have no effect on incubating eggs/alevins.

Compared with the No Action Alternative, the modeled December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the upper water temperature objective of 56°F to protect spawning spring-run Chinook salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11; Asarian et al. 2023). Like the No Action Alternative, seasonal flow releases under Alternative 1 are also expected to maintain a relatively low risk of disease outbreaks for spring-run Chinook salmon by maintaining minimum flows and relatively cool water temperatures.

Compared with the No Action Alternative, the increased monthly average flows in December and February under Alternative 1 would likely have negligible impacts on the availability and suitability of spring-run Chinook salmon spawning and incubation habitat in the Trinity River. Overall, the impacts in the reaches most heavily used by spawning spring-run Chinook salmon would likely be negligible or slightly beneficial, with spatial variability related to the impacts of channel geometry on habitat suitability.

Juvenile Rearing and Emigration

In the Trinity River, spring-run Chinook salmon fry emerge from the gravel beginning in December and most emergence is complete by the end of February (Leidy and Leidy 1984). Fry and juvenile Chinook salmon rearing in the Trinity River preferentially use areas of relatively slow water velocity and habitat with woody material, undercut banks, and other complex cover (Hampton 1988, Pinnix et al. 2019). Naturally spawned juvenile spring-run Chinook salmon typically outmigrate as sub-yearlings from the Trinity River and occasionally as yearlings. Hatchery releases of spring-run Chinook salmon also include mostly sub-yearlings and some yearling releases in spring and fall, respectively. Peak outmigration of natural and hatchery origin juveniles occurs in May, June, and July based on monitoring in the lower Trinity River near the town of Willow Creek (Harris et al. 2016; Petros et al. 2017). The effects of flow and water temperature on rearing and emigrating spring-run Chinook salmon may, therefore occur from December through July.

Potential Changes to Spring-run Chinook Salmon Juvenile Rearing and Emigration from Seasonal Operations

Differences in modeled monthly average Trinity River flows between Alternative 1 and the No Action Alternative would occur in December–March of below normal and wetter water years, none of which would be likely to reduce the availability or suitability of juvenile rearing and emigration habitat for spring-run Chinook salmon. In all other months and water year types there would be little or no difference in monthly average flow between Alternative 1 and the No Action Alternative and no effects on spring-run Chinook salmon would be expected.

Modeled monthly average flow in December of wet water years would increase from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1 (Table O-12) and may result in changes in observed and predicted WUA for fry and juvenile spring-run Chinook salmon that would vary by reach (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). From Lewiston Dam to Dutch Creek, fry WUA would increase and juvenile WUA would decrease. In the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, WUA for both fry and juveniles would decrease. From South Fork Trinity River to Weitchpec, fry WUA would increase and juvenile WUA would decrease slightly (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the modeled monthly average flows would increase under Alternative 1 (1,475 cfs) compared with the No Action (1,194 cfs) with similar effects on WUA for fry and juvenile spring-run Chinook salmon in all reaches as the December flow increase. In March of below normal water years, the decrease in modeled monthly average flows from 427 cfs under the No Action Alternative to 349 cfs under Alternative 1 would increase the amount of observed and predicted WUA for Chinook salmon fry and juveniles in all reaches of the mainstem Trinity River (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999), with potential benefits to rearing and emigrating spring-run Chinook salmon. Where the channel is naturally unconfined and not overly incised and in locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships and rearing WUA in some restored areas may exhibit a stronger positive relationship to flow up to approximately 3,500 cfs (Cooper-Hertel et al. 2022). Consequently, spring-run Chinook salmon WUA in all reaches is likely to vary spatially with channel confinement and incision and in WUA in restored areas may be greater than described in U.S. Fish and Wildlife Service and Hoopa Valley Tribe (1999). See Section O.4.24.1.1 for additional details. The changes in WUA for spring-run Chinook salmon fry and juveniles may have minor, short-term effects on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the eight-month rearing period and in some reaches of the Trinity River.

Compared with the No Action Alternative, the December and February flow increases would either reduce monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the 62.6°F water temperature objective for emigrating juvenile spring-run Chinook salmon recommended for normal and wetter water year types and the 68°F objective recommended for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that water temperatures in December and February would remain below both objectives under a wide range of flow scenarios (Asarian et

al. 2023) and there would be no change in the temperature suitability for rearing or emigrating spring-run Chinook salmon under Alternative 1 relative to the No Action Alternative. The flow reduction in March of below normal water years would increase monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative (Figure O-17) but this change would be unlikely to result in any exceedance of the water temperature objectives at Weitchpec in any water year type (Asarian et al. 2023) and no effects on rearing or emigrating spring-run Chinook salmon are expected.

Compared with the No Action Alternative, the increased monthly average flows in December and February and the reduced monthly average flow in March under Alternative 1 would cause only negligible changes in factors affecting the availability or suitability of spring-run Chinook salmon rearing and emigration habitat.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon typically enter the Trinity River from April through September. By the end of July, most fish have arrived at the primary spawning reach, which extends from Lewiston Dam downstream to the confluence with the North Fork Trinity River. After entering freshwater, spring-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically begins in late September (Leidy and Leidy 1984; Gough et al. 2019, 2021a,b). The effects of flow and water temperature on migrating and holding spring-run Chinook salmon adults may therefore occur from April through September.

Potential Changes to Spring-run Chinook Salmon Adult Upstream Migration and Holding from Seasonal Operations

Under Alternative 1, there would be no expected change in habitat conditions for spring-run Chinook salmon upstream migration and holding compared with the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish. During the primary spring-run Chinook salmon upstream migration and holding period from April through September there would be no differences in modeled monthly average flow between the two alternatives and no differences in modeled monthly average water temperature. Compared with the No Action Alternative, there would be no impacts on spring-run Chinook salmon adult upstream migration and holding.

O.4.27 Upper Klamath-Trinity River Fall-run Chinook Salmon ESU

O.4.27.1 Trinity River

Spawning and Egg/Alevin Incubation

Most fall-run Chinook salmon in the Trinity River spawn from late October to December, with a peak in spawning occurring in November (Myers et al. 1998, Leidy and Leidy 1984). Optimal spawning temperatures for spawning are reported to be less than 55.4°F (Moyle 2002). At optimal intragravel temperatures (43–54°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another 4–6 weeks (Moyle 2002). In the Trinity River, fall-run Chinook salmon incubation and emergence typically occurs from December through late February (Leidy and Leidy 1984). The effects of flow and water temperature on fall-run Chinook

salmon spawning and egg/alevin incubation may therefore occur from approximately mid-October through February.

Potential Changes to Fall-run Chinook Salmon Spawning and Egg/Alevin Incubation from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 to flows under the No Action Alternative. Monthly flow differences, most less than 5%, in December–February of below normal and wetter water year types would have minor and potentially beneficial effects on the availability or suitability of spawning and egg/alevin incubation habitat for fall-run Chinook salmon relative to the No Action Alternative. Under Alternative 1, like the No Action Alternative, the variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

During the late October to November spawning period there would be no difference in modeled monthly average flows between Alternative 1 and the No Action Alternative (Table O-12). Average flows from September through February when fall-run Chinook salmon egg/alevin incubation occurs would be equal to or greater than 300 cfs in all water year types, and substantially greater in the wettest water years in some months, to provide suitable conditions for incubation and emergence. In December when fall-run Chinook salmon eggs and alevins are incubating in the Trinity River, modeled monthly average flow would increase substantially (by more than 5%) in wet water years from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1. Later in the incubation period, modeled monthly average flows in February of above normal water years would increase substantially (more than 5%) from 1,194 cfs under the No Action Alternative to 1,475 cfs under Alternative 1. In all reaches of the Trinity River, the effects of flow changes on spawning suitability are likely to vary spatially with channel confinement and incision (Goodman et al. 2018). Where the channel is naturally unconfined and not overly incised and where channel restoration has removed remnant riparian berms and reduced legacy channel confinement and incision, a stronger positive relationship between flow and salmonid habitat suitability, particularly for flows of approximately 400–1,200 cfs, can be expected than in areas of greater channel confinement (see Section O.4.24.1.1 for additional details). This is mainly a result of increasing habitat area, which also provides more space for redds and reduces the risk of redd superimposition by later-spawning salmonids. The increased December and February average flows are not expected to reduce suitability for incubating Chinook salmon eggs/alevins, and the December flow increase may reduce risk of redd superimposition by spawning spring-run Chinook salmon and coho salmon. The monthly average flows in the Trinity River below Lewiston during the fall-run Chinook salmon egg/alevin incubation period would be too low to cause redd scour, and modeled monthly average flow increases under Alternative 1 would therefore have no effect on the risk of redd scour relative to the No Action Alternative. The probability of redd scour in the primary salmon spawning reaches of the Trinity River is predicted to be less than 1% at flows up to 5,000 cfs (Gaeuman et al. 2023).

Compared with the No Action Alternative, the modeled December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely

remain well below the upper water temperature objective of 56°F to protect spawning fall-run Chinook salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11; Asarian et al. 2023). Like the No Action Alternative, seasonal flow releases under Alternative 1 are also expected to maintain a relatively low risk of disease outbreaks for fall-run Chinook salmon by maintaining minimum flows and relatively cool water temperatures.

Compared with the No Action Alternative, the increased monthly average flows in December and February under Alternative 1 would likely have minor impacts on the availability and suitability of fall-run Chinook salmon spawning and incubation habitat in the Trinity River. Overall, the impacts in the reaches most heavily used by spawning spring-run Chinook salmon would likely be negligible or slightly beneficial, with spatial variability related to the impacts of channel geometry on habitat suitability.

Juvenile Rearing and Emigration

In the Trinity River, fall-run Chinook salmon fry emerge from the gravel beginning in December and most emergence is complete by mid-April. Natural juvenile fall-run Chinook salmon primarily outmigrate as sub-yearlings from the Trinity River and less occasionally as yearlings Hatchery releases of fall-run Chinook salmon also include mostly smolts primarily released in late spring and fall. Peak outmigration occurs in March, April, and May but can extend to July based on monitoring in the lower Trinity River near the town of Willow Creek (Moyle 2002, Chesney and Yokel 2004). The effects of flow and water temperature on rearing and emigrating fall-run Chinook salmon may therefore occur primarily from December through July.

Potential Changes to Fall-run Chinook Salmon Juvenile Rearing and Emigration from Seasonal Operations

Differences in modeled monthly average Trinity River flows between Alternative 1 and the No Action Alternative would occur in December–March of below normal and wetter water years, none of which would be likely to reduce the availability or suitability of juvenile rearing and emigration habitat for fall-run Chinook salmon. In all other months and water year types there would be little or no difference in monthly average flow between Alternative 1 and the No Action Alternative and no effects on fall-run Chinook salmon would be expected.

Modeled monthly average flow in December of wet water years would increase from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1 (Table O-12) and may result in changes in observed and predicted WUA for fry and juvenile fall-run Chinook salmon that would vary by reach (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). From Lewiston Dam to Dutch Creek, fry WUA would increase and juvenile WUA would decrease. In the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, WUA for both fry and juveniles would decrease. From South Fork Trinity River to Weitchpec, fry WUA would increase and juvenile WUA would decrease slightly (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the modeled monthly average flows would increase under Alternative 1 (1,475 cfs) compared with the No Action (1,194 cfs) with similar effects on WUA for fry and juvenile fall-run Chinook salmon in all reaches as the December flow increase. In March of below normal water years, the decrease in modeled monthly average flows from 427 cfs under the No Action Alternative to 349 cfs under Alternative 1 would increase the amount of observed and predicted WUA for Chinook salmon fry and juveniles in all reaches of the mainstem Trinity River (U.S. Fish and Wildlife

Service & Hoopa Valley Tribe 1999), with potential benefits to rearing and emigrating fall-run Chinook salmon. Where the channel is naturally unconfined and not overly incised and in locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships and rearing WUA in some restored areas may exhibit a stronger positive relationship to flow up to approximately 3,500 cfs (Cooper-Hertel et al. 2022). Consequently, fall-run Chinook salmon WUA in all reaches is likely to vary spatially with channel confinement and incision and in WUA in restored areas may be greater than described in U.S. Fish and Wildlife Service and Hoopa Valley Tribe (1999) at all but the lowest flows. See Section O.4.24.1.1 for additional details. The changes in WUA for fall-run Chinook salmon fry and juveniles may have minor, short-term, and potentially beneficial effects on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the rearing period and in some reaches of the Trinity River.

Compared with the No Action Alternative, the December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the 62.6°F water temperature objective for emigrating juvenile fall-run Chinook salmon recommended for normal and wetter water year types and the 68°F objective recommended for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that water temperatures in December and February would remain below both objectives under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating fall-run Chinook salmon under Alternative 1 relative to the No Action Alternative. The flow reduction in March of below normal water years would increase modeled monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative (Figure O-17) but this change would be unlikely to result in any exceedance of the water temperature objectives at Weitchpec in any water year type (Asarian et al. 2023) and no impacts on rearing or emigrating fall-run Chinook salmon are expected.

Compared with the No Action Alternative, the increased monthly average flows in December and February and the reduced monthly average flow in March under Alternative 1 would cause only negligible changes in factors affecting the availability or suitability of fall-run Chinook salmon rearing and emigration habitat and may result in minor beneficial impacts.

Adult Upstream Migration and Holding

Adult fall-run Chinook salmon typically enter the Trinity River from September through October (Moyle et al. 2015). Two to four weeks after river entry, adults have made it to the primary spawning reach which extends from Lewiston Dam downstream to the mouth of the North Fork Trinity River. After entering freshwater, fall-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically ranges from the third week of September through November, peaking in October (Chensey and Knechtle 2012). The effects of flow and water temperature on migrating and holding fall-run Chinook salmon adults may therefore occur from August through November.

Potential Changes to Fall-run Chinook Salmon Adult Upstream Migration and Holding from Seasonal Operations

Under Alternative 1, there would be no expected change in habitat conditions for fall-run Chinook salmon upstream migration and pre-spawning compared with the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish including Chinook salmon. During the primary fall-run Chinook salmon upstream migration and pre-spawning period from September through October there would be no differences in modeled monthly average flow between the two alternatives and no differences in modeled monthly average water temperature. Compared with the No Action Alternative, there would be no impacts on adult fall-run Chinook salmon during the upstream migration and pre-spawning period.

O.4.28 Klamath Mountains Province Steelhead DPS

O.4.28.1 Trinity River

Spawning and Egg/Alevin Incubation

Spawning across run types in the Trinity River may occur anytime from December through May so effects of flow and water temperature on spawning may occur during this period.

Steelhead eggs and alevins across run types in the Trinity River may be present in the gravel from December through June, so effects of flow and water temperature on steelhead eggs and alevins may occur during this period.

Potential Changes to Steelhead Spawning and Egg/Alevin Incubation from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 to flows under the No Action Alternative. Minor differences, most less than 5%, in December–April of below normal and wetter water year types would have variable effects on the availability or suitability of spawning and egg/alevin incubation habitat for steelhead relative to the No Action Alternative (Table O-12).

In December when modeled monthly average flow would increase substantially (by more than 5%) in wet water years from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1 (Table O-12). The December flow increase would have little to no change in the WUA of steelhead spawning habitat from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

In February of above normal water years, the greater than 5% increase in modeled monthly average flows from 1,194 cfs under the No Action Alternative to 1,475 cfs under Alternative 1, would have little to no change in WUA of steelhead spawning habitat from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

The effects of the modeled flow increases from December wet water years and February above normal water years on spawning suitability in the reach from Lewiston to Dutch Creek is uncertain because WUA in this reach has not been quantified for flows above 800 cfs (U.S. Fish and Wildlife Service and Hoopa Valley Tribe 1999).

In March of below normal water years, the greater than 5% decrease in modeled monthly average flows from 427 cfs under the No Action Alternative to 349 cfs under Alternative 1, would have little to no change in WUA of steelhead spawning habitat from Lewiston Dam to Weitchpec (U.S. Fish and Wildlife Service and Hoopa Valley Tribe 1999).

The relationships between seasonal operations and WUA derived from the Trinity River Flow Evaluation (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999) are assumed to provide generally applicable characterization of flow-related effects in the Trinity River however there is some uncertainty in how WUA has changed with restoration projects in the Trinity River which is described in more detail in Section O.4.26.

Compared to the No Action Alternative, the modeled December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the upper water temperature objective of 56°F to protect spawning salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11).

The flow reduction in March of below normal water years would increase the modeled monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative (Figure O-17). However, this change would be unlikely to result in any exceedance of the 56°F water temperature objective in the reach from Lewiston Dam to North Fork Trinity River (Asarian et al. 2023) and no effects on spawning or incubating steelhead are expected. Like the No Action Alternative, seasonal flow releases under Alternative 1 are also expected to maintain a relatively low risk of disease outbreaks for steelhead by maintaining minimum flows and relatively cool water temperatures.

Compared to the No Action Alternative, the increased monthly average flows in December and February and the reduced monthly average flow in March under Alternative 1 would likely have little to no change on the availability and suitability of steelhead spawning and incubation habitat in the Trinity River, but there is some uncertainty due to the variable impacts of channel geometry on habitat suitability.

Juvenile Rearing and Emigration

Rearing or moving (migrating or redistributing) fry and/or juveniles can occur downstream of Lewiston Dam any time of year with three peak emigration times in March, May/June, and October/November.

Potential Changes to Steelhead Juvenile Rearing and Emigration from Seasonal Operations

Minor differences in Trinity River flows between Alternative 1 and the No Action Alternative would occur in December–March of below normal and wetter water years, with both adverse and beneficial effects on the availability of suitable juvenile rearing and emigration habitat for steelhead depending on month, reach, and life stage. In all other months and water year types there would be little or no difference in monthly average flow between Alternative 1 and the No Action Alternative and no effects on steelhead would be expected.

Monthly average flow in December in wet water years would increase from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1 (Table O-12) and may result in negligible changes in observed and predicted WUA for steelhead fry that would vary by reach (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Minor potential increases in WUA for fry would occur from Lewiston Dam to Dutch Creek and from South Fork Trinity to Weitchpec and minor decreases from Dutch Creek to South Fork Trinity (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The same modeled change in December in wet water years may result in little to no change in overwintering juvenile rearing habitat and negligible decreases in a couple reaches for remaining (non-overwintering) juvenile rearing habitat.

In February of above normal water years, the monthly average flows would increase under Alternative 1 (1,475 cfs) compared to the No Action (1,194 cfs) (Table O-12) and may result in negligible changes in observed and predicted WUA for steelhead fry that would vary by reach. Minor potential increases in WUA for steelhead fry would occur from Lewiston Dam to Dutch Creek and minor potential decreases from Dutch Creek to South Fork Trinity and little to no change in fry WUA from South Fork Trinity to Weitchpec. The same modeled changes in February of wet water years may result in slight decreases in juvenile WUA from Lewiston Dam to Weitchpec.

In March of below normal water years, the decrease in monthly average flows from 427 cfs under the No Action Alternative to 349 cfs under Alternative 1 would increase the amount of observed and predicted WUA for steelhead fry in all reaches of the mainstem Trinity River (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999), with potential benefits to rearing steelhead fry. The same modeled change in March of below normal water years under Alternative 1 would have little to no change in observed and predicted WUA for juvenile steelhead.

These changes in WUA for steelhead fry and juveniles may have minor, short-term effects on the ability of these life stages and potentially some benefits for fry in March, to access cover and preferred habitat in the Trinity River.

Compared to the No Action Alternative, the December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the 59°F water temperature objective for emigrating salmon recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in December and February would remain below the 59°F objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating steelhead under Alternative 1 relative to the No Action Alternative. The flow reduction in March of below normal water years would increase modeled monthly average water temperature below Lewiston by approximately 1°F relative to the No Action Alternative (Figure O-17) but this change would be unlikely to result in any exceedance of the 59°F water temperature objective at Weitchpec (Asarian et al. 2023) and no effects on rearing or emigrating steelhead are expected. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 1 through July at Douglas City but would not be met at the North Fork

Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the steelhead rearing and emigration period at downstream locations in some water year types under Alternative 1, water temperatures and the potential effects on steelhead would not differ from the No Action Alternative.

Compared to the No Action Alternative, the increased monthly average flows in December and February and the reduced monthly average flow in March under Alternative 1 would cause only negligible changes in factors affecting the availability or suitability of steelhead rearing and emigration habitat and substantial adverse impacts on steelhead would be unlikely.

Adult Upstream Migration and Holding

Consistent adult monitoring data are limited by environmental conditions and challenges in overlapping populations with different run timing, kelting or "runbacks", and half pounders but summer/fall steelhead (stream-maturing steelhead) are thought to return from the ocean about April through November and hold for varying lengths of time in the Klamath-Trinity watershed (Moyle et al. 2017, Moyle et al. 2015, Pinnix et al 2007). Winter steelhead (ocean-maturing steelhead) can return from the ocean about November through March (Moyle et al. 2017, Moyle et al. 2015, Pinnix et al 2007). Given the overlapping run timings and varying life history strategies, adults at various stages of maturation can enter the Klamath-Trinity watershed, hold in Trinity River, and/or migrate up or down Trinity River and into tributaries in any month of the year.

Potential Changes to Steelhead Adult Upstream Migration and Holding from Seasonal Operations

Under Alternative 1, seasonal operations in the Trinity River are expected to provide similar or better habitat conditions for steelhead migration and holding than the No Action Alternative.

Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish, including steelhead. There would be no differences in modeled monthly average flow between the two alternatives in May through October; negligible differences in November, January, and April; a substantial increase in December of wet water years; a substantial increase in February of above normal water years; and a substantial decrease in March of below normal water years (Table O-12).

Monthly average flow in December in wet water years would increase from 1,133 cfs under the No Action Alternative to 1,212 cfs under Alternative 1 (Table O-12) and may result in little to no change in observed and predicted WUA for adult steelhead holding from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

In February of above normal water years, the monthly average flows would increase under Alternative 1 (1,475 cfs) compared to the No Action (1,194 cfs) (Table O-12) and may result in increases in observed and predicted WUA for adult steelhead holding from Dutch Creek to North Fork Trinity and from South Fork Trinity to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999) and little to no change between North Fork Trinity and South Fork Trinity.

In March of below normal water years, the decrease in monthly average flows from 427 cfs under the No Action Alternative to 349 cfs under Alternative 1 would decrease the amount of observed and predicted WUA for adult steelhead holding in all reaches of the mainstem Trinity River (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999), with potential adverse effects to holding adult steelhead.

These changes in WUA for adult holding steelhead may have benefits for adult holding steelhead in February and adverse effects on adult holding steelhead in March but holding in February and March is likely short-lived as fall and winter-run steelhead move into spawning territories relatively quickly compared to holding behavior earlier in the season by summer-run which occurs for several months. Therefore, the potential effects of changes in flow on holding steelhead WUA would be negligible.

Modeled monthly average flows in August and September and water temperatures that are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 1 as under the No Action Alternative. Under both alternatives, August and September flows of 760 cfs in wet water years and 863 cfs in all other water year types would maintain suitable water temperatures for adult upstream migration (60°F in August and early September and 56°F in late September (Table O-11). During late September to mid-November, the monthly average flows under Alternative 1 would also be the same as the No Action Alternative and would help maintain suitable water temperatures for migration. In December of wet water years, the increased monthly average flows would help maintain suitable water temperatures for adult upstream migration and holding. Like the No Action Alternative, seasonal flow releases under Alternative 1 are expected to maintain a low risk of disease outbreaks for steelhead by maintaining minimum flows and relatively cool water temperatures.

Although WUA for adult steelhead upstream migration is not available for the Trinity River, the modeled flow increase in December of wet water years and February of above normal water years under Alternative 1 may slightly increase suitability for migrating adults by increasing water depth in some areas and increasing the volume of holding pools. However, the decrease in March of below normal water years may decrease suitability for migrating adults by decreasing water depth in some areas and decreasing volume of holding pools. The number of years with increases (estimated at about 42%) would be more than the number of years with decreases (18%) so there would likely be little change or a slight benefit to migrating adult steelhead from Alternative 1 compared to the No Action Alternative.

Compared to the No Action Alternative, seasonal operations under Alternative 1 would likely provide some benefits for migrating steelhead in the Trinity River and have little to no impact on holding.

O.4.29 Northern DPS Green Sturgeon

O.4.29.1 Trinity River

Spawning and Egg Incubation

Northern DPS green sturgeon adults spawn primarily from March through July, though most spawning takes place from April to June (O.1.2.5.1, *Green Sturgeon, Northern DPS*). Northern DPS green sturgeon eggs hatch approximately a week after fertilization, and optimal temperatures for incubation range from 51.8–62.6°F (Eenennaam et al. 2005). The effects analysis period for incubating eggs is considered to be the same as the spawning period due to the short incubation period and includes March through July.

Potential Changes to Northern DPS Green Sturgeon Spawning and Egg Incubation from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be similar to flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would be unlikely to reduce the availability or suitability of spawning pools and egg incubation habitat for green sturgeon and could improve water velocity and depth in holding pool habitats during above normal years. During the spawning window, flows under Alternative 1 would be almost identical to those under the No Action Alternative, except for a greater than 5% flow reduction in March of below normal water years. This reduction would still allow flows of 300 cfs and likely would not be detrimental to suitable spawning habitat or egg incubation.

Green sturgeon are only known to occur within the lower 43 miles of the Trinity River, ranging as far upstream as Grays Falls near Burnt Ranch, approximately 70 miles downstream of Lewiston Dam (Benson et al. 2007). Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries). Results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations would not likely have a detectable influence on the water temperature suitability for spawning and egg incubation of green sturgeon.

Larval and Juvenile Rearing and Emigration

The northern DPS green sturgeon spawning period is from March through July, and the larval period is considered to be March through September. The juvenile stage of green sturgeon begins when metamorphosis of the larva is complete, typically about 45 days after hatching and approximately up to 2 cm TL. Juveniles (up to 150 cm TL) typically slowly migrate downstream, and rear in the Lower Klamath River for up to a year or until approximately their first summer, with optimal growth temperatures ranging from 59–66.2°F (Moyle 2002; Mayfield and Cech, Jr.

2004). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near Burnt Ranch to the Klamath River Estuary (Section O.1.2.5.1, *Green Sturgeon, Northern DPS*). The effects analysis period for larval and juvenile life stages in the Trinity River should be considered to be from April to September.

Potential Changes to Northern DPS Green Sturgeon Larval and Juvenile Rearing and Emigration from Seasonal Operations

Minor differences in Trinity River flows between Alternative 1 and the No Action Alternative would occur in March of below normal and wet water years. Any minor differences would be unlikely to reduce the availability or suitability of juvenile rearing and emigration habitat for green sturgeon. Monthly average flow under Alternative 1 compared with the No Action Alternative in March of below normal water years would still allow for flows of 300 cfs and would be unlikely to have detrimental effects on rearing habitat. Greater than 5% flow increases under Alternative 1 compared with the No Action Alternative during wet and above normal years would provide increased water velocity in rearing habitats and would likely provide little to some increased habitat suitability for juvenile rearing and emigration. Under Alternative 1, flows during summer months would be almost identical to those under the No Action Alternative during juvenile downstream emigration periods.

Green sturgeon larvae and juveniles are only known to occur within the lower 43 miles of the Trinity River; after hatching, they begin to migrate downstream. Water temperatures and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River. The results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows between 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations would not likely have a detectable influence on the water temperature suitability for larval and juvenile rearing and emigration of green sturgeon.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Trinity River from the Klamath River Estuary as early as February to make their way upstream to spawn in deep pools from the lower section of the mainstem Trinity River to the confluence with the Klamath River, approximately 43 miles to Gray's Falls near Burnt Ranch. After spawning, the adults remain in mainstem river pools for varying amounts of time, representing distinct migration patterns. Directly after spawning, 25% emigrate back to the Klamath River estuary and ocean, but freshwater residency may last up to 199 days (Moyle 2002, Section O.1.3.2.5, *Green Sturgeon, Northern DPS*). With the extended adult holding period, effects analysis period of flow and water temperature on adult upstream immigration, holding, and emigration may occur from February through December.

Potential Changes to Northern DPS Green Sturgeon Adult Upstream Migration and Holding from Seasonal Operations

Under Alternative 1, seasonal operations in the Trinity River are expected to provide similar or better habitat conditions for adult green sturgeon upstream migration, emigration, and holding than the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish. During the green sturgeon upstream migration and holding period, a greater than 5% increase in flows would occur under the No Action Alternative in February of above normal years, and a greater than 5% decrease in flows would occur in March of below normal years. The increase in flows in February would provide adequate upstream passage and pool holding habitat. The decrease in flows in March would have a minor effect on migration and holding of adults because modeled releases would decrease from 427 to 300 cfs. Monthly average flows during summer and fall months when green sturgeon adults are more likely to emigrate to the ocean would be at or above 300 cfs in all water year types and would provide adequate flows for downstream movements and pool habitats.

Green sturgeon adults are only known to occur within the lower 43 miles of the Trinity River, and they have variable freshwater residence time (Benson et al. 2007). Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43 and a smaller temperature differences expected downstream of RM 43 to the confluence of the Trinity and Klamath rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations would not likely have a detectable influence on the water temperature suitability for migration and holding of adult green sturgeon.

O.4.30 Eulachon

O.4.30.1 Lower Klamath River from Confluence with Trinity River to Pacific Ocean

Spawning and Egg Incubation

Eulachon adults spawn from December and through May, with peak spawning occurring in March and April (O.1.2.6 *Eulachon*). Eulachon eggs hatch in 20 to 40 days depending on water temperature, with cooler temperatures leading to longer incubation times. Spawning is reported to occur at temperatures from 39 to 50°F; colder temperatures may stop migration (National Marine Fisheries Service 2017a). The effects analysis period for eulachon spawning and egg incubation is December through June.

Potential Changes to Eulachon Spawning and Egg Incubation from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would be unlikely to reduce the availability or suitability of spawning pools and egg incubation habitat for eulachon

and could improve water velocity during above normal years. During the spawning and egg incubation window of December through June, Alternative 1 compared to the No Action Alternative is almost identical except for a greater than 5% reduction of flow in March during below normal water years. This reduction would still allow flows of at least 300 cfs and likely would not be detrimental to suitable spawning habitat or egg incubation.

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature and habitat conditions within this section Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries). Previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 1 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for spawning and egg incubation of eulachon in the Lower Klamath River.

Larval Emigration

Eulachon spawning period is from December through May and eggs hatch in 20 to 40 days, so the larval period is considered to be January through June. After hatching, larval eulachon are quickly carried out to the ocean by river currents (Scott and Crossman 1973). Larval eulachon only remain in the Klamath River for about five days until they are washed out to sea. Larvae live on their yolk sac reserves after hatching—they do not feed while in fresh water (Gustafson et al. 2022). Effects of flow and water temperature on eulachon larvae may occur from January through June in the Klamath River.

Potential Changes to Eulachon Larval Emigration from Seasonal Operations

Greater than 5% decreases in Trinity River flows between Alternative 1 and the No Action Alternative are modeled to occur in March of below normal years. This decrease would be unlikely to negatively impact eulachon larval emigration as Alternative 1 would still allow for flows of 300 cfs. Other minor decreases of less than 5% in Trinity River flows between Alternative 1 and the No Action Alternative would occur in January of above normal years. This difference is not likely to have a detectable impact on eulachon larval emigration. Greater than 5% increases in flow under Alternative 1 compared to the No Action Alternative during above normal years in February could provide increased water velocity to the river but are not likely to have a detectable influence on eulachon larval emigration.

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Eulachon larvae are washed downstream to the ocean immediately after hatching. Water temperature and habitat conditions within this section Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of

previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 1 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for eulachon larval emigration.

Adult Upstream Migration

The spawning migration period for adult eulachon in the Klamath River begins in December and continues until May, with peak migration occurring in March and April (Yurok Tribal Fisheries Program 1998; Larson and Belchik 1998, Section O.1.2.6). Eulachon distribution in the Trinity River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Eulachon are broadcast spawners most commonly over sand, though spawning substrates can range from silt, sand or gravel to cobble and detritus (California Department of Fish and Wildlife 2010; National Marine Fisheries Service 2017a). Eulachon usually die after spawning. The effects analysis period for eulachon adult upstream migration is December through May.

Potential Changes to Eulachon Adult Upstream Migration from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative. Minor differences, less than 5%, in December of above normal water years would be unlikely to impact eulachon adult upstream migration. During the spawning window of December through May, Alternative 1 has an increase in flows of greater than 5% during wet years and above normal years. There is also a greater than 5% reduction in flows in March during below normal water years. The increase or reduction in modeled flows under Alternative 1 would be unlikely to impact eulachon adult upstream migration.

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature and habitat conditions within this section Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 1 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for eulachon adult upstream migration.

O.4.31 Coastal Cutthroat Trout

O.4.31.1 Lower Klamath River from Confluence with Trinity River to Pacific Ocean

Spawning and Egg Incubation

Generally, spawning of anadromous and resident coastal cutthroat trout may occur from September to April (Moyle 2002). Coastal cutthroat trout are associated with shaded streams and instream cover with water temperatures below 64°F, while preferred temperatures range from 48–54°F, with spawning temperatures of 43–63°F. (Moyle 2002). Spawning habitat is typically found in headwater streams with 1–3 feet/sec flow velocities and unembedded small- to medium-sized gravel (0.08–4 inches) (Moyle 2002). Embryos hatch about 6–7 weeks following incubation and alevins emerge 1–2 weeks thereafter (Moyle 2002).

The effects analysis period for coastal cutthroat trout spawning and egg incubation is September through June.

Potential Changes to Coastal Cutthroat Trout Spawning and Egg Incubation from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would be unlikely to reduce the availability or suitability of coastal cutthroat trout spawning pools and egg incubation habitat in adjacent tributaries as Trinity River flows do not impact tributaries.

Seasonal operations under Alternative 1 are not expected to impact suitable habitat conditions for coastal cutthroat trout spawning and egg incubation in the Trinity River. Compared with the No Action Alternative, changes in the availability or suitability of coastal cutthroat trout juvenile spawning and egg incubation habitat under Alternative 1 would likely be negligible since Trinity River flows do not impact tributaries where coastal cutthroat trout spawn.

Juvenile Rearing and Emigration

Juvenile coastal cutthroat trout may spend anywhere from one to three years in freshwater to rear. Cutthroat fry are typically associated with slow water velocities (less than 1 foot/sec, while prefer <0.3 feet/sec), and trout are typically found in shaded streams with instream cover and water temperatures below 64°F, while preferred temperatures range from 48–54°F (Moyle 2002).

For the amphidromous life history, most coastal cutthroat trout leave their streams for the summer months and return to overwinter in fresh water, even as non-spawning fish (Moyle 2002). During outmigration, many of the trout migrate to estuaries or lagoons and if they do go to the ocean, they remain close to the coast (Moyle 2002). In a Klamath River tributary, yearling and older cutthroat emigration occurred mainly between April and June (Moyle 2002). For individuals that emigrated to an estuary, Wallace (2004) found that the residence time within the estuary ranged from 5 to 89 days, with a mean of 27 days. Resident coastal cutthroat trout will remain in freshwater their entire lives, rather than emigrating to a lagoon or estuary or the ocean.

The effects analysis period for coastal cutthroat trout juvenile rearing and emigration is April through June for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout.

Potential Changes to Coastal Cutthroat Trout Juvenile Rearing and Emigration from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would be unlikely to reduce the availability or suitability of juvenile rearing and emigration habitat for coastal cutthroat trout. Alternative 1 compared to the No Action Alternative has a greater than 5% reduction of flow in March during below normal water years and a greater than 5% increase in flows in December of wet water years and February of above normal water years. The flow reductions during below normal water years would still allow flows of at least 300 cfs, and the combined influence of both the upper Klamath River and several tributaries that enter the Trinity River are unlikely to have a detectable influence on coastal cutthroat trout juvenile rearing and emigration.

Water temperature and habitat conditions within the Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 1 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for coastal cutthroat trout juvenile rearing and emigration.

Seasonal operations under Alternative 1 are expected to maintain suitable habitat conditions for coastal cutthroat trout juvenile rearing and emigration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of coastal cutthroat trout juvenile rearing and emigration habitat would be minimal under Alternative 1 and unlikely to have adverse impacts on coastal cutthroat trout.

Adult Holding and Migration

Migration of coastal cutthroat trout to freshwater typically occurs between August and October between the ages of one and five (Moyle 2002). While most anadromous salmonids die after completing spawning, coastal cutthroat may survive spawning, re-enter the ocean, and return the following year(s) to spawn up to five times (Moyle 2002). Overwintering coastal cutthroat trout prefer pools with cover (e.g., logs, undercut banks, boulders) (Moyle 2002).

The effects analysis period for coastal cutthroat trout adult holding and migration is August through October for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout.

Potential Changes to Coastal Cutthroat Trout Adult Holding and Migration from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would be unlikely to reduce the availability or suitability of juvenile rearing and emigration habitat for coastal cutthroat trout. Alternative 1 compared to the No Action Alternative has a greater than 5% reduction of flow in March during below normal water years and a greater than 5% increase in flows in December of wet water years and February of above normal water years. The flow reductions during below normal water years would still allow flows of at least 300 cfs and with the combined influence of both the upper Klamath River and several tributaries that enter the Trinity River are unlikely to have a detectable influence on coastal cutthroat trout adult holding and migration.

Water temperature and habitat conditions within the Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 1 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for coastal cutthroat trout adult holding and migration.

Seasonal operations under Alternative 1 are expected to maintain suitable habitat conditions for coastal cutthroat trout adult holding and migration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of coastal cutthroat trout adult holding and migration habitat would be minimal and unlikely to have adverse impacts on coastal cutthroat trout.

O.4.32 Brown Trout

O.4.32.1 Trinity River

Spawning and Egg Incubation

Brown trout spawn in fall and winter, most commonly in November and December in California (Moyle 2002). Trout typically mature and spawn in their second or third year, but they may wait longer (7 or 8 years) (Moyle 2002). Adults begin selecting spawning locations when water temperatures are between 42.8–50°F (Moyle 2002). Spawning habitat is comprised of pea- to walnut-sized gravel in less turbulent waters, which are typically found at pool tailouts (Moyle 2002). Embryos hatch in seven–eight weeks (ranging from four–21 weeks), with alevins emerging three–six weeks later, depending on water temperature.

The effects analysis period for brown trout spawning and egg incubation is November through April.

Potential Changes to Brown Trout Spawning and Egg Incubation from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam would generally be higher than or similar under Alternative 1 to flows under the No Action Alternative. Minor differences, most less than 5%, in December–April of below normal and wetter water year types would have variable effects on the availability or suitability of spawning and egg/alevin incubation habitat for brown trout relative to the No Action Alternative (Table O-12).

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would be unlikely to reduce the availability or suitability of spawning pools and egg incubation habitat for brown trout and could improve water velocity during wet and above normal years. During the spawning and egg incubation window of November through April, Alternative 1 compared to the No Action Alternative has a 18% reduction (78 cfs difference from the No Action Alternative) of flow in March during below normal water years and a greater than 5% increase in flows in December of wet water years and February of above normal water years. The flow reductions during normal water years would still allow flows of at least 300 cfs and likely would not be detrimental to suitable spawning habitat or egg incubation.

Compared to the No Action Alternative, the modeled December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the upper water temperature objective of 56°F (Table O-11).

Seasonal operations under Alternative 1 are expected to maintain suitable habitat conditions for brown trout spawning and egg incubation in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout spawning and egg incubation habitat would be minimal and unlikely to have adverse impacts on brown trout.

Juvenile Rearing and Emigration

The ideal temperature range for brown trout is between 53.6–68°F, with optimal growth between 62.6–64.4°F; they can survive for only short period at higher temperatures up to 84.2°F (Moyle 2002). Cold temperatures reduce brown trout's ability to effectively capture prey: when temperatures reduced from 58.5°F to 42.3°F the foraging effectiveness reduced from 96% to 53% (Watz and Piccolo 2010, as cited in Asarian et al., 2023).

In California, brown trout reach 2–3 inches in length their first year, 5–6 inches in their second year, 8–11 inches in their third, and 14–16 inches in their fourth year (Moyle 2002). Fry rear in edge-water habitat that is slow and shallow (<12 inches deep), with juveniles selecting riffles and pools with deeper water (20–30 inches), higher velocities (0.3–1.3 feet/second), and cover from overhead, rocks, and logs (Moyle 2002). It is uncertain the degree to which brown trout exhibit an anadromous life history in the Trinity River, with juveniles emigrating to the ocean, or are riverine (potamodromous) with juveniles emigrating further downstream while continuing to remain in freshwater. In Ireland, where they are native, brown trout juveniles emigrated to brackish or marine habitats throughout the year, with distinct seasonal peeks in spring (March through June) and fall (September through December) (Wynne et al. 2023).

The effects analysis period for brown trout juvenile rearing and emigration is January through December.

Potential Changes to Brown Trout Juvenile Rearing and Emigration from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would be unlikely to reduce the availability or suitability of juvenile rearing and emigration habitat for brown trout and could improve water velocity during wet and above normal years. Alternative 1 compared to the No Action Alternative has a 18% reduction of flow in March during below normal water years and a greater than 5% increase in flows in December of wet water years and February of above normal water years. The flow reductions during normal water years would still allow flows of at least 300 cfs and likely would not be detrimental to brown trout juvenile rearing and emigration.

Compared to the No Action Alternative, the modeled December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the upper water temperature objective of 56°F (Table O-11).

Seasonal operations under Alternative 1 are expected to maintain suitable habitat conditions for brown trout juvenile rearing and emigration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout juvenile rearing and emigration habitat would be minimal and unlikely to have adverse impacts on brown trout.

Adult Holding and Migration

Upstream migration occurs in fall and winter, prior to spawning, which most commonly occurs in November and December. Sullivan and Hilemean (2018) noted a shift in migration timing on the Trinity River to later in the season following the implementation of the Record of Decision (ROD) flows (2005-2011, 2017), as compared to the between baseline Pre-ROD flows (1982–2002). In rivers, adults will hold in a wide range of habitats, but are often associated with low velocity pools ranging from 2.3–11.5 feet deep that have cover (Moyle 2002).

The effects analysis period for brown trout adult holding and migration is January through December with migration primarily in November and December.

Potential Changes to Brown Trout Adult Holding and Migration from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 1 would generally be higher than or similar to flows under the No Action Alternative. Minor differences, most less than 5%, in December–March of below normal and wetter water year types would be unlikely to reduce the availability or suitability of adult holding and migration habitat for brown trout and could improve water velocity during wet and above normal years. Alternative 1 compared to the No Action Alternative has a 12% of flow in March during below normal water years and a greater than 5% increase in flows in December of wet water years and February of above normal water years. The flow reductions during normal water years would still allow flows of at least 300 cfs and likely would not be detrimental to brown trout adult holding and migration.

Compared to the No Action Alternative, the modeled December and February flow increases would either reduce modeled monthly average water temperatures in the Trinity River below Lewiston or cause no change, and average water temperatures under Alternative 1 would likely remain well below the upper water temperature objective of 56°F (Table O-11).

Seasonal operations under Alternative 1 are expected to maintain suitable habitat conditions for brown trout adult holding and migration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout adult holding and migration habitat would be minimal and unlikely to have adverse impacts on brown trout.

O.4.33 Trinity Reservoir Species

O.4.33.1 Trinity Reservoir

Spawning and Egg Incubation

Coldwater fish species (rainbow trout, brown trout, Kokanee, and landlocked Chinook salmon) in the lake generally migrate into tributaries to spawn either during from December through March (rainbow trout), November–December (brown trout), or August through April (kokanee). Populations of rainbow trout, brown trout, and Kokanee are sustained through a combination of natural reproduction and fish hatchery stocking practices. Landlocked Chinook salmon do not typically reproduce (Perales et al. 2015) and are supported by annual stocking practices.

Warmwater fish species (smallmouth bass, largemouth bass, white catfish, and brown bullhead) typically rely on habitat in the lake during all life stages. In general, smallmouth and largemouth bass spawn from April through July in shallow water (1.5 feet to 6.0 feet deep) along the lake margins at water temperatures ranging from 55°F to 75°F (Moyle 2002). These nests are vulnerable to fluctuations in water levels. Rapid drops in water levels may cause guarding males to abandon the nests, increase predation, and limit water circulation and dissolved oxygen levels around the eggs (USFWS 1983, Habitat Suitability Information: Smallmouth Bass, FWS/OBS-82/10.36). White catfish spawning typically occurs during June and July when water temperatures exceed 68°F, but spawning can sometimes extend into September; spawning occurs in sandy substrate adjacent to cover (e.g., rocks, wood, or aquatic vegetation) and eggs hatch in about a week (Moyle 2002). Brown bullhead spawn from May through mid-July and will build their nests in sand or gravel near cover (Moyle 2002). Warmwater fish species in Trinity Lake are currently self-sustaining through natural reproduction.

The effects analysis period for coldwater fish species spawning and egg incubation is August through April. The effects analysis period for warmwater fish species spawning and egg incubation is April through September.

Potential Changes to Trinity Reservoir Fish Species Spawning and Egg Incubation from Seasonal Operations

Trinity Reservoir storage under Alternative 1 would generally be higher than storage under the No Action Alternative, except in above normal years in February through April, and July and in critically dry years July through December when Trinity Reservoir storage would be slightly lower than the No Action Alternative (Table O-13). All changes between Alternative 1 and the No Action Alternative would be minor (less than 5%) and are unlikely to have a detectable

influence on the water temperature and habitat suitability for spawning and egg incubation of Trinity Reservoir coldwater or warmwater fish species.

Larval and Juvenile Rearing and Emigration

Rainbow trout fry emerge 3–4 weeks after fertilization and will remain in the gravel for about 2–3 weeks (Moyle 2002, USFWS 1984, Habitat Suitability Information: Rainbow Trout, FWS/OBS-82/10.60). Juvenile rainbow trout may spend two summers in their natal stream and two summers in a reservoir or lake before maturing. Brown trout fry typically hatch in 2 months, though it can range from 1–5 months depending on water temperature, and larvae will emerge from the gravel around 1 month later. Juveniles will spend several years in tributaries before emigrating to the reservoir where they will become sexually mature (Moyle 2002; Belica 2007).

Smallmouth and largemouth bass fry prefer shallow water and are vulnerable to fluctuations in water levels. These fry hatch in 2–7 days and then spend another week in the nest. Larval bass stay in shallow water on the edge of vegetation (Moyle 2002). Rapid drops in water levels may cause stranding. Juvenile bass tend to live in deeper water habitats with submerged shelter (e.g., logs or boulders). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002).

The effects analysis period for both coldwater and warmwater fish species larval and juvenile rearing and emigration is January through December.

Potential Changes to Trinity Reservoir Fish Species Larval and Juvenile Rearing and Emigration from Seasonal Operations

Trinity Reservoir storage under Alternative 1 would generally be higher than storage under the No Action Alternative, except in above normal years in February through April, and July and in critically dry years July through December when Trinity Reservoir storage would be slightly lower than the No Action Alternative (Table O-13). All changes between Alternative 1 and the No Action Alternative would be minor (less than 5%) and are unlikely to have a detectable influence on the water temperature and habitat suitability for larval and juvenile rearing and emigration of Trinity Reservoir coldwater or warmwater fish species.

<u>Adult Holding</u>

The life expectancy of rainbow trout can be 4–8 years in northern California lake populations. After maturing, resident rainbow trout will migrate upstream to spawn in tributaries. They can spawn annually and will quickly move back downstream to the reservoir or lake (Moyle 2002), moving to cooler, deeper waters during the summer months (Belica 2007). Brown trout typically become sexually mature at age two or three and have been found as old as can live for up to nine years in California, spawning several times during their life (Moyle 2002, Belica 2007). Brown trout will use varying habitats within the reservoir and will also move to cooler waters in the summer habitats (Belica 2007).

Warmwater species will remain in the reservoir their entire lives. Smallmouth bass prefer narrow bays and upstream ends of reservoirs or along the shore where rocky shelves are present at a depth of 1–10m (Moyle 2002). They become sexually mature at age three to four–4and typically live less than seven years (USFWS 1983, Habitat Suitability Information: Smallmouth Bass, FWS/OBS-82/10.36). Age of largemouth bass in California reservoirs is four to five years and they typically spawn during their second season (Moyle 2002). Adult bass tend to prefer deeper, colder waters in lakes and reservoirs in areas with vegetation and other forms of cover (USFWS 1983, Habitat Suitability Information: Largemouth Bass, FWS/OBS-82/10.16). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002). They become sexually mature at age three and will spawn multiple times during their lifetime of up to eight 0 years (Moyle 2002).

The effects analysis period for both coldwater and warmwater fish species adult holding is January through December.

Potential Changes to Trinity Reservoir Fish Species Adult Holding from Seasonal Operations

Trinity Reservoir storage under Alternative 1 would generally be higher than storage under the No Action Alternative, except in above normal years in February through April, and July and in critically dry years July through December when Trinity Reservoir storage would be slightly lower than the No Action Alternative (Table O-13). All changes between Alternative 1 and the No Action Alternative would be minor (less than 5%) and are unlikely to have a detectable influence on the water temperature and habitat suitability for adult holding of Trinity Reservoir coldwater or warmwater fish species.

O.4.34 Central Valley Reservoir Species

O.4.34.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations

Methods

This section describes the analysis used to evaluate potential effects on warm water and cold water fish species from changes in LTO operations in Central Valley reservoirs, including Shasta Reservoir, Whiskeytown Dam, Folsom Reservoir, and New Melones Reservoir.

Reservoir fish species may be sensitive to changes in water surface elevations and reservoir storage resulting from changes in operations. Effects resulting from these changes are focused on specific life stage requirements of focal warm water and cold water fish species. The primary effect mechanism for warm water fish species including black basses are changes to water surface elevations. Outside of flood control and water delivery operational effects, changes in water surface elevations would generally decrease in summer and fall months and increase in winter and spring months as a result of inflows from seasonal precipitation patterns and snowmelt. During summer months, the upper portions of reservoirs will increase in temperature, creating preferable habitat for warm water species while reducing available habitat for cold water species. Cold water species, including trout and kokanee, are primarily affected by changes in reservoir storage volumes. Monthly reservoir storage and water surface elevation model outputs from CalSim 3 were used to analyze potential effects on reservoir fish species.

Effects to reservoir water temperatures from operations under each alternative were also considered. However, changes in reservoir water temperatures are not expected to adversely affect warm water fish. For example, largemouth bass spawning has been observed between 52.7° F and 84.2° F (Stuber et al. 1982). Due to their wide range in water temperature tolerance, it is anticipated that there would be sufficient habitat quantity with suitable water temperatures in which warm water fish could successfully spawn. Therefore, no further water temperature evaluation for warm water species was conducted.

Warmwater Fish Species: Reservoir Water Surface Elevation

This analysis was adapted from similar analyses used in the Lower Yuba River Accord EIR Addendum Number 2 (Yuba County Water Agency (2014) and the Sites Reservoir FEIR/FEIS, Appendix 11E (Sites Project Authority and Bureau of Reclamation 2023). Water surface elevations (WSEs) in reservoirs represent specific habitat features for fish assemblages. Warm water fish species typically inhabit upper layers of reservoirs, which in turn makes these species more susceptible to effects from changes in surface water elevations. Reductions in water surface elevation could lead to disrupted spawning behavior, nest dewatering, and egg desiccation of black basses during their spawning and egg incubation period in California reservoirs (~March through June; Lee 1999, Moyle 2002). Many studies have found that a nest success rate of 40% to 60% will result in a self-sustaining black bass population in North America (Latta 1963, Forbes 1981, Philipp et al. 1997, Friesen 1998, Knotek and Orth 1998, Hunt and Annett 2002, Steinhart 2004). Based on a relationship from Lee (1999), a 60% nest success rate for largemouth bass and smallmouth bass can be achieved with a month-over-month reduction rate of approximately 6 feet or less. Therefore, a month-over-month reduction in reservoir WSE of 6 feet or more per month was selected as the threshold beyond which an adverse impact on spawning success could occur.

CalSim 3 reports end-of-month reservoir WSEs. Therefore, WSEs from February to June were used in this analysis (i.e., March fluctuation rate = March end of month WSE – February end of month elevation).

Coldwater Fish Species: Reservoir Storage Volume

Average monthly reservoir storage volumes were modeled to evaluate potential effects on cold water species during April through November. Although aquatic habitat is not expected to be limiting in Central Valley reservoirs, changes in storage volume are representative of habitat availability for cold water species inhabiting the reservoirs. A reduction in storage volume by 5% or greater compared to the No Action Alternative would represent a loss in habitat, signifying a negative effect on cold water species.

Results

Shasta Reservoir

<u>Warmwater Species</u>

Reductions in Shasta Reservoir WSE month-over-month reductions of six feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warm water reservoir species. These results are presented in Table O-165. There would be similar or slightly more WSE

reductions of six feet or more under Alternative 1 relative to the No Action Alternative. These results indicate that Alternative 1 would have generally negligible effects on warm water species in Shasta Reservoir.

Table O-165. Difference in Shasta Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June[1]

Comparison	Difference in Water Surface Elevation Reductions of 6 Feet or More over the 100-Year Period of Record			
	March	April	May	June
Alternative 1 Relative to No Action Alternative	0	3	0	1
Alternative 2 with TUCP without VA Relative to No Action Alternative	0	1	-8	-3
Alternative 2 without TUCP without VA Relative to No Action Alternative	0	2	-9	-2
Alternative 2 without TUCP Delta VA Relative to No Action Alternative	0	2	-9	-3
Alternative 2 without TUCP Systemwide VA Relative to No Action Alternative	0	3	-8	-6
Alternative 3 Relative to No Action Alternative	-1	-3	0	-16
Alternative 4 Relative to No Action Alternative	0	2	-8	-2

[1] A positive number indicates that there were more reductions under the alternative than under the No Action Alternative; a negative number indicates that there were fewer reductions under the alternative than under the No Action Alternative

Coldwater Species

Shasta Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on cold water reservoir species. These results are presented in Table O-166. Differences in storage between Alternative 1 and the No Action Alternative would be small (<5%) except in above normal years during September and October, when storage would be 5.3% and 6.1% greater, respectively, under Alternative 1 than the No Action Alternative. These results indicate that Alternative 1 would generally have negligible effects on cold water reservoir species in Shasta Reservoir.

Table O-166. Percent Difference in Shasta Reservoir Storage Volume between Each Alternative and the No Action Alternative, April through October [1]

WYT	Month	Alt1 vs. NAA	Alt2 wTUCP woVA vs. NAA	Alt2 woTUCP woVA vs. NAA	Alt2 woTUCP DeltaVA vs. NAA	Alt2 woTUCP AllVA vs. NAA	Alt3 vs. NAA	Alt4 vs. NAA
W	4	0.4	0.0	0.0	0.0	-0.6	-0.1	0.0
W	5	0.0	0.0	0.0	0.0	-0.1	-3.4	0.0
W	6	-0.9	0.0	-0.1	0.0	0.8	-1.7	0.0
W	7	-0.2	0.4	0.4	0.4	0.6	-1.2	0.0
W	8	0.8	0.6	0.6	0.5	-0.1	-0.6	0.0
W	9	1.8	0.5	0.4	0.4	-1.4	0.8	0.0
W	10	1.7	0.5	0.4	0.3	-1.3	0.9	0.0
AN	4	1.0	-0.1	-0.1	-0.1	-1.9	-0.3	0.0
AN	5	0.5	-0.1	-0.1	0.0	-1.5	-3.1	0.0
AN	6	-1.5	-0.1	-0.1	0.1	1.6	-0.6	0.0
AN	7	-0.2	1.1	1.1	1.1	1.7	2.0	0.1
AN	8	2.3	1.7	1.7	1.7	0.2	2.3	0.1
AN	9	5.3	1.2	1.2	1.2	-3.4	4.3	0.1
AN	10	6.1	0.3	0.3	0.2	-4.8	4.7	0.1
BN	4	-0.4	1.8	0.0	0.1	-0.4	3.2	1.8
BN	5	-0.3	2.5	0.8	1.0	0.2	3.2	1.7
BN	6	-2.0	2.5	0.9	1.0	3.1	4.7	1.6
BN	7	-1.1	4.1	2.4	2.6	4.3	5.9	1.1
BN	8	1.2	5.3	3.6	3.8	3.6	4.7	0.9
BN	9	-0.2	4.7	2.9	3.2	4.2	5.0	0.8
BN	10	-0.1	5.1	3.2	3.4	4.0	5.8	0.5
D	4	2.0	1.4	1.1	1.3	-0.3	4.4	0.4
D	5	2.3	2.3	2.1	2.2	0.7	4.4	0.3
D	6	2.2	3.4	3.1	3.4	2.5	4.5	0.1
D	7	2.8	5.7	5.3	5.2	4.4	2.9	0.0
D	8	2.7	5.4	5.0	4.9	4.4	-0.2	-0.1
D	9	2.8	5.4	4.9	4.9	4.3	0.8	-0.2
D	10	2.6	5.1	4.6	4.6	4.3	0.7	-0.2
C	4	0.9	7.6	-0.7	0.4	0.6	5.9	5.0

WYT	Month	Alt1 vs. NAA	Alt2 wTUCP woVA vs. NAA	Alt2 woTUCP woVA vs. NAA	Alt2 woTUCP DeltaVA vs. NAA	Alt2 woTUCP AllVA vs. NAA	Alt3 vs. NAA	Alt4 vs. NAA
C	5	0.5	10.8	1.6	2.9	2.9	6.9	5.4
C	6	0.3	16.0	5.0	6.4	6.8	6.3	6.6
C	7	-1.5	26.2	8.5	10.3	12.7	4.8	11.1
C	8	0.1	32.3	11.2	13.6	14.4	3.2	12.8
C	9	1.9	33.8	12.6	15.5	14.3	4.6	11.8
C	10	2.7	32.4	11.2	13.8	11.8	7.4	11.3
All	4	0.8	1.4	0.2	0.4	-0.6	2.2	1.0
All	5	0.6	2.1	0.8	1.0	0.2	0.8	0.9
All	6	-0.4	2.7	1.3	1.5	2.3	1.9	1.0
All	7	0.2	4.7	2.7	2.9	3.4	2.2	1.3
All	8	1.5	5.3	3.2	3.4	2.8	1.3	1.3
All	9	2.2	5.2	3.0	3.3	1.9	2.5	1.2
All	10	2.4	4.7	2.7	2.9	1.3	2.9	1.0

[1] A positive number indicates that storage volume is higher under the alternative compared to the No Action Alternative; a negative number indicates that storage volume is lower under the alternative compared to the No Action Alternative

Whiskeytown Reservoir

Warmwater Species

Reductions in Whiskeytown Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warm water reservoir species. These results are presented in Table O-167. There would be no difference in any month in the number of month-over-month water surface elevation reductions of 6 feet or more between Alternative 1 and the No Action Alternative. This indicates that there would be no effect of Alternative 1 on warm water reservoir species in Whiskeytown Reservoir.

Table O-167. Difference in Whiskeytown Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June[1]

Comparison	Difference in Water Surface Elevation Reductions of 6 Feet or More over the 100-Year Period of Record			
	March	April	May	June
Alternative 1 Relative to No Action Alternative	0	0	0	0
Alternative 2 with TUCP without VA Relative to No Action Alternative	0	0	1	0
Alternative 2 without TUCP without VA Relative to No Action Alternative	0	0	1	1
Alternative 2 without TUCP Delta VA Relative to No Action Alternative	0	0	1	1
Alternative 2 without TUCP Systemwide VA Relative to No Action Alternative	0	0	1	1
Alternative 3 Relative to No Action Alternative	0	0	0	-1
Alternative 4 Relative to No Action Alternative	0	0	1	0

[1] A positive number indicates that there were more reductions under the alternative than under the No Action Alternative; a negative number indicates that there were fewer reductions under the alternative than under the No Action Alternative

Coldwater Species

Whiskeytown Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on cold water reservoir species. These results are presented in Table O-168. End-of-month storage volume under Alternative 1 would be similar to that of the No Action Alternative. These results indicate that Alternative 1 would have negligible effects on cold water species in Whiskeytown Reservoir.

Table O-168. Percent Difference in Whiskeytown Reservoir Storage Volume between Each Alternative and the No Action Alternative, April through October[1]

WYT	Month	Alt1 vs. NAA	Alt2 wTUCP woVA vs. NAA	Alt2 woTUCP woVA vs. NAA	Alt2 woTUCP DeltaVA vs. NAA	Alt2 woTUCP AllVA vs. NAA	Alt3 vs. NAA	Alt4 vs. NAA
W	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	5	0.2	-0.2	-0.2	-0.2	-0.3	-0.1	0.0
W	6	0.5	0.4	0.4	0.4	0.0	0.0	0.0
W	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	10	0.6	0.6	0.6	0.6	0.0	0.0	0.0
AN	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	5	0.1	0.1	0.1	0.1	0.0	-0.4	0.0
AN	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	5	0.2	0.0	0.0	0.0	-0.2	-0.5	-0.1
BN	6	0.0	-0.3	-0.5	-0.5	-0.5	0.3	0.0
BN	7	0.0	0.0	-1.4	-1.4	-1.4	0.0	1.4
BN	8	0.0	2.9	0.0	0.0	0.0	0.0	1.4
BN	9	0.0	1.4	0.0	0.0	0.0	0.0	1.2
BN	10	0.0	1.5	0.2	0.2	0.2	0.3	0.8
D	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	5	0.1	-0.4	-0.4	-0.4	-0.6	0.1	0.0
D	6	0.0	-0.4	-0.4	-0.4	-0.3	0.4	0.0
D	7	0.0	-0.3	0.0	0.0	0.0	0.3	0.0
D	8	1.1	0.6	0.9	0.9	-0.2	0.5	0.0
D	9	0.2	-0.6	-0.2	-0.2	-0.4	1.6	0.0
D	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	4	0.9	1.5	-0.9	-0.7	-1.1	-0.7	1.2

WYT	Month	Alt1 vs. NAA	Alt2 wTUCP woVA vs. NAA	Alt2 woTUCP woVA vs. NAA	Alt2 woTUCP DeltaVA vs. NAA	Alt2 woTUCP AllVA vs. NAA	Alt3 vs. NAA	Alt4 vs. NAA
C	5	0.9	-2.8	-2.7	-2.8	-3.6	1.3	1.6
C	6	1.5	-1.9	-2.0	-2.0	-3.5	2.1	0.9
C	7	-0.2	-1.3	-3.1	-3.1	-1.3	2.1	1.4
C	8	-0.8	0.5	-2.7	-2.5	-1.7	2.6	2.3
C	9	-0.3	4.7	1.5	1.8	2.1	2.7	2.0
C	10	-0.1	4.8	2.5	2.5	2.5	1.2	1.8
All	4	0.1	0.2	-0.1	-0.1	-0.2	-0.1	0.2
All	5	0.3	-0.6	-0.6	-0.6	-0.8	0.1	0.2
All	6	0.4	-0.3	-0.4	-0.4	-0.7	0.5	0.2
All	7	0.0	-0.3	-0.7	-0.7	-0.5	0.4	0.5
All	8	0.1	0.7	-0.2	-0.2	-0.3	0.5	0.6
All	9	0.0	0.8	0.2	0.2	0.2	0.8	0.5
All	10	0.2	1.1	0.5	0.6	0.4	0.2	0.4

[1] A positive number indicates that storage volume is higher under the alternative compared to the No Action Alternative; a negative number indicates that storage volume is lower under the alternative compared to the No Action Alternative

Folsom Reservoir

Warmwater Species

Reductions in Folsom Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warm water reservoir species. These results are presented in Table O-169. There would be between 1 and 17 more reductions in WSE under Alternative 1 than under the No Action Alternative, depending on month. These results suggest that there would be a negative effect to warm water species in Folsom Reservoir.

Table O-169. Difference in Folsom Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June[1]

Comparison	Difference in Water Surface Elevation Reductions of 6 Feet or More over the 100-Year Period of Record			
	March	April	May	June
Alternative 1 Relative to No Action Alternative	1	6	2	17
Alternative 2 with TUCP without VA Relative to No Action Alternative	1	0	2	2
Alternative 2 without TUCP without VA Relative to No Action Alternative	2	4	1	3
Alternative 2 without TUCP Delta VA Relative to No Action Alternative	2	3	0	2
Alternative 2 without TUCP Systemwide VA Relative to No Action Alternative	1	3	2	2
Alternative 3 Relative to No Action Alternative	1	0	-3	-20
Alternative 4 Relative to No Action Alternative	0	0	2	4

[1] A positive number indicates that there were more reductions under the alternative than under the No Action Alternative; a negative number indicates that there were fewer reductions under the alternative than under the No Action Alternative

Coldwater Species

Folsom Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on cold water reservoir species. These results are presented in Table O-170. Storage under Alternative 1 would be similar to or up to 16.6% greater than storage under the No Action Alternative. These results indicate that Alternative 1 would have beneficial effects to cold water species in Folsom Reservoir.

Table O-170. Percent Difference in Folsom Reservoir Storage Volume between Each Alternative and the No Action Alternative, April through October[1]

WYT	Month	Alt1 vs. NAA	Alt2 wTUCP woVA vs. NAA	Alt2 woTUCP woVA vs. NAA	Alt2 woTUCP DeltaVA vs. NAA	Alt2 woTUCP AllVA vs. NAA	Alt3 vs. NAA	Alt4 vs. NAA
W	4	0.5	0.0	0.0	0.0	-0.5	-2.4	0.0
W	5	0.6	0.0	0.0	0.0	-0.6	-2.3	0.0
W	6	-2.1	-0.2	-0.2	-0.1	2.1	0.7	0.0
W	7	1.7	0.5	0.5	0.2	-1.8	-0.1	0.0
W	8	3.4	0.9	0.8	0.7	-2.9	-0.9	0.0
W	9	5.3	0.8	0.7	0.4	-4.8	0.8	0.1
W	10	3.8	0.6	0.4	0.4	-3.3	0.9	0.1
AN	4	0.9	0.1	0.1	0.1	-0.8	-8.3	0.0
AN	5	0.4	-0.4	-0.4	-0.6	-1.1	-8.5	0.0
AN	6	-2.3	-1.4	-1.3	-1.2	1.1	1.5	0.0
AN	7	5.1	1.2	1.2	-0.1	-5.7	8.7	0.0
AN	8	8.5	0.5	0.7	0.4	-7.6	4.6	0.0
AN	9	13.5	-0.2	0.1	-1.0	-11.8	7.2	0.0
AN	10	12.8	-1.1	-0.9	-1.3	-11.9	8.5	0.1
BN	4	2.8	0.7	0.7	0.7	-2.1	-11.1	0.0
BN	5	2.2	-0.3	-0.4	-0.1	-1.7	-8.7	0.2
BN	6	-4.2	-0.4	-0.5	-0.2	5.0	-0.6	-0.2
BN	7	3.6	2.5	2.5	2.4	-1.6	10.4	-1.1
BN	8	4.5	1.5	1.7	0.8	-2.2	8.6	-1.7
BN	9	6.6	1.9	2.1	0.8	-4.8	7.2	-2.4
BN	10	8.0	3.0	4.4	2.6	-4.5	7.3	-3.4
D	4	7.8	2.1	1.9	2.0	-4.8	-7.4	0.1
D	5	6.2	-0.4	-0.6	-0.3	-4.6	-3.5	0.4
D	6	4.9	0.3	0.0	-0.2	-2.7	3.6	0.2
D	7	3.3	-1.7	-1.9	-2.5	-2.6	8.6	-0.4
D	8	5.6	-1.3	-1.6	-2.9	-3.5	2.9	0.2
D	9	16.6	-0.5	-0.8	-2.3	-11.6	2.2	0.1
D	10	14.9	0.6	0.3	-0.9	-8.9	2.3	0.0
C	4	0.0	5.8	-11.5	-13.1	-11.9	-10.0	20.4

WYT	Month	Alt1 vs. NAA	Alt2 wTUCP woVA vs. NAA	Alt2 woTUCP woVA vs. NAA	Alt2 woTUCP DeltaVA vs. NAA	Alt2 woTUCP AllVA vs. NAA	Alt3 vs. NAA	Alt4 vs. NAA
C	5	4.4	5.9	-7.4	-9.1	-11.9	-10.4	14.4
C	6	-1.2	5.7	-11.5	-12.3	-10.2	-7.9	19.3
C	7	-2.1	4.1	-12.7	-13.7	-10.8	-6.6	16.7
C	8	-3.6	8.0	-9.0	-11.4	-6.0	-7.1	16.2
C	9	1.7	9.9	-7.8	-9.5	-9.1	-8.6	16.4
C	10	2.0	10.9	-7.5	-9.3	-9.6	-9.4	17.7
All	4	2.5	1.3	-0.7	-0.8	-3.0	-7.0	2.0
All	5	2.5	0.4	-1.0	-1.2	-3.0	-5.6	1.5
All	6	-1.0	0.3	-1.6	-1.6	0.1	0.2	1.8
All	7	2.4	0.9	-1.1	-1.7	-3.5	4.0	1.4
All	8	4.0	1.3	-0.7	-1.5	-3.9	1.5	1.4
All	9	8.7	1.6	-0.4	-1.4	-7.9	1.9	1.4
All	10	8.1	1.8	0.0	-0.8	-6.8	2.2	1.2

[1] A positive number indicates that storage volume is higher under the alternative compared to the No Action Alternative; a negative number indicates that storage volume is lower under the alternative compared to the No Action Alternative

New Melones Reservoir

Warmwater Species

Reductions in New Melones Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warm water reservoir species. These results are presented in Table O-171. There would be between zero and five more reductions in WSE under Alternative 1 than under the No Action Alternative, depending on month. These results suggest that there would be a marginally negative effect to warm water species in New Melones Reservoir.

Table O-171. Difference in New Melones Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June[1]

Comparison	Difference in Water Surface Elevation Reductions of 6 Feet or More over the 100-Year Period of Record			
	March	April	May	June
Alternative 1 Relative to No Action Alternative	0	1	5	3
Alternative 2 with TUCP without VA Relative to No Action Alternative	0	-1	-2	-1
Alternative 2 without TUCP without VA Relative to No Action Alternative	0	-1	-2	-1
Alternative 2 without TUCP Delta VA Relative to No Action Alternative	0	-1	-2	-1
Alternative 2 without TUCP Systemwide VA Relative to No Action Alternative	0	-1	-2	-1
Alternative 3 Relative to No Action Alternative	0	-2	-6	-5
Alternative 4 Relative to No Action Alternative	0	-1	-2	-1

[1] A positive number indicates that there were more reductions under the alternative than under the No Action Alternative; a negative number indicates that there were fewer reductions under the alternative than under the No Action Alternative

Coldwater Species

New Melones Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on cold water reservoir species. These results are presented in Table O-172. Storage under Alternative 1 would be up to 5.0% lower and up to 5.5% greater than storage under the No Action Alternative depending on month and water year type. These results indicate that Alternative 1 would have marginally beneficial and negative effects to cold water species in New Melones Reservoir.

Table O-172. Percent Difference in New Melones Reservoir Storage Volume between Each Alternative and the No Action Alternative, April through October[1]

WYT	Month	Alt1 vs. NAA	Alt2 wTUCP woVA vs. NAA	Alt2 woTUCP woVA vs. NAA	Alt2 woTUCP DeltaVA vs. NAA	Alt2 woTUCP AllVA vs. NAA	Alt3 vs. NAA	Alt4 vs. NAA
W	4	1.0	0.6	0.5	0.5	-0.6	-2.5	0.1
W	5	0.9	0.5	0.4	0.4	-0.5	-2.7	0.1
W	6	0.3	0.8	0.7	0.7	0.4	-4.1	0.1
W	7	0.3	0.9	0.8	0.8	0.4	-3.6	0.1
W	8	0.5	0.8	0.7	0.7	0.2	-2.2	0.1
W	9	0.5	0.8	0.7	0.7	0.2	-1.7	0.1
W	10	1.2	0.9	0.7	0.7	-0.5	-1.7	0.1
AN	4	-1.7	-0.2	-0.2	-0.2	1.6	-4.0	0.0
AN	5	-1.6	0.1	0.1	0.1	1.7	-4.6	0.0
AN	6	-2.1	0.2	0.2	0.2	2.3	-4.6	0.0
AN	7	-2.2	0.2	0.2	0.2	2.5	-4.2	0.0
AN	8	-2.3	0.2	0.2	0.2	2.6	-3.9	0.0
AN	9	-2.4	0.2	0.2	0.2	2.7	-3.9	0.0
AN	10	-0.4	0.3	0.3	0.3	0.7	-3.7	0.0
BN	4	-1.2	0.7	0.6	0.6	1.7	-4.2	0.1
BN	5	-1.9	1.2	1.0	1.0	3.0	-4.5	0.1
BN	6	-2.1	1.3	1.1	1.1	3.3	-4.4	0.1
BN	7	-2.2	1.4	1.2	1.2	3.5	-4.0	0.2
BN	8	-2.4	1.1	1.0	1.0	3.4	-3.5	0.2
BN	9	-2.3	1.1	0.9	0.9	3.3	-3.0	0.2
BN	10	-0.6	1.2	1.0	1.0	1.6	-3.0	0.2
D	4	-3.4	1.2	0.1	0.1	3.7	-3.7	1.1
D	5	-4.3	1.3	0.2	0.2	4.7	-4.1	1.1
D	6	-4.6	1.3	0.2	0.2	5.0	-4.1	1.1
D	7	-4.8	1.4	0.2	0.2	5.3	-3.9	1.2
D	8	-5.1	1.5	0.2	0.3	5.6	-3.8	1.2
D	9	-5.2	1.5	0.2	0.3	5.7	-3.8	1.2
D	10	-3.5	1.5	0.3	0.3	3.9	-3.8	1.3
C	4	1.5	0.4	0.0	0.0	-1.5	-3.3	0.3

WYT	Month	Alt1 vs. NAA	Alt2 wTUCP woVA vs. NAA	Alt2 woTUCP woVA vs. NAA	Alt2 woTUCP DeltaVA vs. NAA	Alt2 woTUCP AllVA vs. NAA	Alt3 vs. NAA	Alt4 vs. NAA
C	5	1.2	0.4	0.0	0.0	-1.1	-3.2	0.3
C	6	1.2	-0.4	-1.1	-1.1	-2.3	-2.4	0.7
C	7	1.3	-1.2	-2.4	-2.4	-3.6	-1.5	1.2
C	8	1.4	-2.1	-3.8	-3.8	-5.1	-0.4	1.8
C	9	1.4	-2.2	-3.9	-3.9	-5.3	-0.3	1.8
C	10	5.5	-2.4	-4.4	-4.4	-9.4	-0.5	2.1
All	4	-0.8	0.6	0.3	0.3	1.0	-3.4	0.3
All	5	-1.2	0.7	0.4	0.4	1.5	-3.7	0.3
All	6	-1.5	0.8	0.4	0.4	1.9	-4.0	0.4
All	7	-1.6	0.8	0.3	0.3	1.9	-3.6	0.5
All	8	-1.6	0.6	0.1	0.1	1.7	-2.9	0.5
All	9	-1.6	0.6	0.1	0.1	1.7	-2.6	0.5
All	10	-0.1	0.7	0.1	0.1	0.2	-2.6	0.6

[1] A positive number indicates that storage volume is higher under the alternative compared to the No Action Alternative; a negative number indicates that storage volume is lower under the alternative compared to the No Action Alternative

O.4.35 Delta-Mendota Canal/California Aqueduct Species

O.4.35.1 Potential Changes to Delta-Mendota Canal/California Aqueduct Species from Seasonal Operations

Water from the Delta is diverted through the California Aqueduct and Delta-Mendota Canal and held for off-stream storage (e.g., in San Luis Reservoir) and there is no cold water habitat in the Delta-Mendota Canal. Therefore, no analysis of cold water habitat was conducted. Warm water species such as black basses and striped bass support recreational fishing in the California Aqueduct. Water velocity in the canal is not specifically managed to support or enhance recreational fisheries. Increases in water velocity may decrease water temperatures and flowing water for species, improving conditions; while decreases in water velocity may increase water temperatures and lead to stagnant water for species, diminishing conditions.

Differences in flows and velocity under Alternative 1, compared to the No Action Alternative, are expected to be minimal thus, impacts to species present are not expected to change.

O.4.36 San Luis Reservoir Species

O.4.36.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations

Water temperature stratification in San Luis Reservoir is typically eliminated by pumping relatively warm water in through the inlet located near the bottom. In addition, releases are made through an intake/outlet structure near the bottom of the reservoir. As a result, there is no cold water habitat in the reservoir and the fish community is dominated by warm water species like largemouth bass and striped bass. Therefore, no analysis of cold water habitat was conducted in San Luis Reservoir.

Warmwater Species

Reductions in San Luis Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warm water reservoir species. Please see Section O.4.33.2, *Methods,* for details on the methods used in this analysis. Results are presented in Table O-173. Results would range from 1 more to 19 fewer month-over-month reductions under Alternative 1 relative to the No Action Alternative. These results suggest that there would be beneficial effects of Alternative 1 to warm water species in San Luis Reservoir.

Table O-173. Difference in San Luis Reservoir Water Surface Elevation Month-Over-Month Reductions of 6 feet or more between Each Alternative and the No Action Alternative (Difference in Number of Reductions), March to June [1]

	Difference in Water Surface Elevation Reductions of 6 Feet or More over the 100-Year Period of Record			
Comparison	March	April	May	June
Alternative 1 Relative to No Action Alternative	1	-19	-7	1
Alternative 2 with TUCP without VA Relative to No Action Alternative	1	-22	-11	0
Alternative 2 without TUCP without VA Relative to No Action Alternative	1	-26	-12	0
Alternative 2 without TUCP Delta VA Relative to No Action Alternative	5	-22	-12	1
Alternative 2 without TUCP Systemwide VA Relative to No Action Alternative	6	-23	-12	1
Alternative 3 Relative to No Action Alternative	22	20	12	-11
Alternative 4 Relative to No Action Alternative	1	-20	-7	2

[1] A positive number indicates that there were more reductions under the alternative than under the No Action Alternative; a negative number indicates that there were fewer reductions under the alternative than under the No Action Alternative

O.4.37 Southern Resident Killer Whale

O.4.37.1 Nearshore Pacific Ocean on the California Coast

Changes in water operations under the alternatives could have the potential to affect Chinook salmon prey for Southern Resident Killer Whale (Southern Resident) relative to the No Action Alternative. Outlined below are expected changes in Southern Resident prey. Four lines of evidence were used (Salmort, XT, CVPIA SIT LCM, and DPM), and Attachment F.7, *Change in Abundance Estimate of Central Vally Chinook Salmon Available to Southern Resident Killer Whales*, provides detailed results of all models and analyses.

Based on the lines of evidence, Alternative 1 is predicted to have an annual abundance of about 232,915 Chinook salmon that survive to adulthood or about 3,497,213 pounds of Chinook salmon biomass in the ocean available as potential prey to Southern Residents. This is about 164 more Chinook salmon or 2,467 pounds more than the No Action Alternative. Alternative 1 may provide a slight benefit to Southern Residents relative to the No Action Alternative but the difference is likely negligible.

O.5 Alternative 2

Alternative 2 (Multi-Agency Consensus), represents actions, approaches, and tradeoffs made to reach consensus among the state and federal fish agencies: Reclamation, CDFW, DWR, NMFS, and USFWS. Alternative 2 consists of four "phases" which are all evaluated to present the maximum possible effects (adverse and beneficial) resulting from operations under any singular phase. The four phases of Alternative 2 include a combination of implementation of a Temporary Urgency Change Petition (TUCP) and adoption of the Voluntary Agreements (VA) and are as follows:

- Alternative 2 Without TUCP Delta VA
- Alternative 2 Without TUCP Without VA
- Alternative 2 Without TUCP Systemwide VA
- Alternative 2 With TUCP Without VA

The phase that confers the maximum effect may vary (e.g., by resource area, species, and life stage) so results are presented for all four phases. The analysis should consider Alternative 2 Without TUCP Delta VA as the initial phase of operation, followed by either Alternative 2 phase Without VA or Systemwide VA, dependent on a process defined in Alternative 2. Reclamation and DWR operations consistent with the VA are described in *Early Implementation* and *Post Early Implementation sections of* Chapter 3*, Proposed Action,* Section 3.7.5, *Spring Delta Outflow*. A fourth Alternative 2 phase includes implementation of TUCP, a tool used during drought conditions as a Drought Toolkit action. Results from the phase which includes implementation of a TUCP (Alternative 2 With TUCP Without VA) are presented but represent more extreme conditions and should not be a focus of the analysis.

O.5.1 Trinity River

O.5.1.1 Trinity River Flows below Lewiston Dam

CalSim 3 modeling indicates that average monthly flow released at Lewiston Dam under Alternative 2 With TUCP Without VA would be lower than or similar to flow under the No Action Alternative except in above normal water years in February and March when the Alternative 2 With TUCP Without VA flows would be substantially higher (greater than 5% increase) than the No Action Alternative flows (Table O-174). Average monthly flows would be substantially lower (greater than 5% decrease) under Alternative 2 With TUCP Without VA in wet years in February; above normal years in November; and below normal years in December. Table O-174 shows that the highest flows for both alternatives are expected primarily in May and June of all water year types and during winter, spring, and early summer of wet and above normal water years. Throughout the full simulation period, flows on average are slightly lower (2% or less) under Alternative 2 With TUCP Without VA in November through April.

CalSim 3 modeling suggests that average flow released at Lewiston Dam under Alternative 2 Without TUCP Without VA would be lower than or similar to flow under the No Action Alternative, except in above normal water years in February and March when the Alternative 2 Without TUCP Without VA flows would be substantially higher (greater than 5% increase) than the No Action Alternative flows (Table O-175). Average monthly flows would be substantially lower (greater than 5% decrease) under Alternative 2 Without TUCP Without VA in wet years in February; above normal years in November, and below normal years in December (Table O-175). Table O-175 shows that the highest flows for both alternatives are expected primarily in May and June of all water year types and during winter, spring, and early summer of wet and above normal water years. Throughout the full simulation period, flows on average are slightly lower (2% or less) under Alternative 2 Without TUCP Without VA in November through April.

CalSim 3 modeling suggests that average flow released at Lewiston Dam under Alternative 2 Without TUCP With Delta VA would be lower than or similar to flow under the No Action Alternative, except in above normal water years in February when the Alternative 2 Without TUCP With Delta VA would be substantially higher (greater than 5% increase) than the No Action Alternative flows (Table O-176). Average monthly flows would be substantially lower (greater than 5% decrease) in wet years in February and above normal years in November (Table O-176). Table O-176 shows that the highest flows for both alternatives are expected primarily in May and June of all water year types and during winter, spring, and early summer of wet water years and January through March and May through July of above normal water year types. Throughout the full simulation period, flows on average are slightly lower (4% or less) under Alternative 2 Without TUCP With Delta VA in November through April.

CalSim 3 modeling suggests that average flow released at Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be lower than or similar to flow under the No Action Alternative except in above normal water years in February when the Alternative 2 Without TUCP With Systemwide VA flows would be substantially higher (greater than 5%) than the No Action Alternative flows (Table O-177). Alternative 2 Without TUCP With Systemwide VA would have substantially lower (greater than 5%) flows in wet years in February and in above normal years in November. Table O-177 shows that the highest flows for both alternatives are expected primarily in May and June of all water year types and during winter, spring, and early summer of wet water years and January through March and May through July of above normal water year types. Throughout the full simulation period, flows on average are slightly lower (3% or less) under Alternative 2 Without TUCP With Systemwide VA in November through April.

O.5.1.2 Trinity Reservoir Storage

CalSim 3 modeling suggests that average monthly Trinity Reservoir storage under Alternative 2 With TUCP Without VA would generally be similar to storage under the No Action Alternative (Table O-178). Table O-178 suggests that Trinity Reservoir storage under Alternative 2 With TUCP Without VA would not increase or decrease greater than 5% throughout the year. Throughout the full simulation period, Trinity Reservoir storage on average is expected to be similar under Alternative 2 With TUCP Without VA than the No Action Alternative across all months.

CalSim 3 modeling suggests that average monthly Trinity Reservoir storage under Alternative 2 Without TUCP Without VA would generally be similar to storage under the No Action Alternative (Table O-179). Table O-179 suggests that Trinity Reservoir storage under Alternative 2 Without TUCP Without VA would not increase or decrease greater than 5% throughout the year. Throughout the full simulation period, Trinity Reservoir storage on average is expected to be similar under Alternative 2 Without TUCP Without VA than the No Action Alternative across all months.

CalSim 3 modeling suggests that average monthly Trinity Reservoir storage under Alternative 2 Without TUCP With Delta VA would generally be similar to storage under the No Action Alternative (Table O-180). Table O-180 suggests that Trinity Reservoir storage under Alternative 2 Without TUCP With Delta VA would not increase or decrease greater than 5% throughout the year. Throughout the full simulation period, Trinity Reservoir storage on average is expected to be similar under Alternative 2 Without TUCP With Delta VA than the No Action Alternative across all months.

CalSim 3 modeling suggests that average monthly Trinity Reservoir storage under Alternative 2 Without TUCP With Systemwide VA would generally be similar to storage under the No Action Alternative (Table O-181). Table O-181 suggests that Trinity Reservoir storage under Alternative 2 Without TUCP With Systemwide VA would not increase or decrease greater than 5% throughout the year. Throughout the full simulation period, Trinity Reservoir storage on average is expected to be similar under Alternative 2 Without TUCP With Systemwide VA than the No Action Alternative across all months.

Table O-174. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	373	393	1,133	1,872	1,843	2,002	1,035	4,637	3,054	1,122	760	760
Above Normal (14%)	373	403	785	1,016	1,194	1,021	552	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	931	300	606	427	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	342	720	840	912	900	682	3,598	1,820	814	834	834
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	373	393	1,152	1,863	1,706	1,925	1,018	4,637	3,054	1,122	760	760
Above Normal (14%)	373	363	753	1,019	1,390	1,095	551	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	880	300	610	442	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	336	711	838	902	892	677	3,598	1,820	814	834	834
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	19	-9	**-137**	-77	-18	0	0	0	0	0
Above Normal (14%)	0	**-41**	-32	3	**196**	**74**	-1	0	0	0	0	0
Below Normal (18%)	0	0	**-51**	0	4	15	0	0	0	0	0	0
Dry (24%)	0	0	0	0	0	0	0	0	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	0	-6	-9	-2	-10	-8	-5	0	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-175. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	373	393	1,133	1,872	1,843	2,002	1,035	4,637	3,054	1,122	760	760
Above Normal (14%)	373	403	785	1,016	1,194	1,021	552	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	931	300	606	427	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	342	720	840	912	900	682	3,598	1,820	814	834	834
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	373	393	1,152	1,862	1,699	1,924	1,018	4,637	3,054	1,122	760	760
Above Normal (14%)	373	362	753	1,019	1,339	1,095	551	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	880	300	610	442	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	336	711	838	893	892	677	3,598	1,820	814	834	834
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	19	-9	**-143**	-79	-17	0	0	0	0	0
Above Normal (14%)	0	**-41**	-32	3	**145**	**74**	-1	0	0	0	0	0
Below Normal (18%)	0	0	**-51**	0	4	15	0	0	0	0	0	0
Dry (24%)	0	0	0	0	0	0	0	0	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	0	-6	-9	-2	-19	-9	-5	0	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-176. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	373	393	1,133	1,872	1,843	2,002	1,035	4,637	3,054	1,122	760	760
Above Normal (14%)	373	403	785	1,016	1,194	1,021	552	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	931	300	606	427	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	342	720	840	912	900	682	3,598	1,820	814	834	834
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	373	393	1,148	1,843	1,693	1,939	1,012	4,637	3,054	1,122	760	760
Above Normal (14%)	373	337	755	1,018	1,258	1,012	550	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	904	300	610	435	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	332	714	833	880	883	675	3,598	1,820	814	834	834
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	15	-28	**-150**	-63	-23	0	0	0	0	0
Above Normal (14%)	0	**-66**	-30	3	**64**	-8	-2	0	0	0	0	0
Below Normal (18%)	0	0	-27	0	4	8	0	0	0	0	0	0
Dry (24%)	0	0	0	0	0	0	0	0	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	0	-10	-5	-8	-32	-17	-7	0	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-177. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	373	393	1,133	1,872	1,843	2,002	1,035	4,637	3,054	1,122	760	760
Above Normal (14%)	373	403	785	1,016	1,194	1,021	552	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	931	300	606	427	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	342	720	840	912	900	682	3,598	1,820	814	834	834
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	373	393	1,152	1,858	1,698	1,944	1,013	4,637	3,054	1,122	760	760
Above Normal (14%)	373	339	750	1,021	1,326	1,012	550	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	928	300	610	431	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	332	719	837	891	883	675	3,598	1,820	814	834	834
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	19	-14	**-144**	-59	-22	0	0	0	0	0
Above Normal (14%)	0	**-64**	-35	5	**132**	-9	-2	0	0	0	0	0
Below Normal (18%)	0	0	-3	0	4	4	0	0	0	0	0	0
Dry (24%)	0	0	0	0	0	0	0	0	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	0	-10	-1	-3	-21	-17	-6	0	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-178. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir storage for the No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,656	1,658	1,709	1,764	1,945	2,061	2,239	2,194	2,105	2,008	1,879	1,745
Above Normal (14%)	1,496	1,518	1,581	1,661	1,837	2,005	2,165	2,079	1,992	1,880	1,702	1,546
Below Normal (18%)	1,263	1,295	1,392	1,536	1,640	1,773	1,900	1,817	1,740	1,602	1,432	1,298
Dry (24%)	1,060	1,100	1,244	1,385	1,492	1,619	1,706	1,606	1,513	1,364	1,199	1,088
Critically Dry (16%)	727	737	810	1,004	1,051	1,123	1,140	1,064	995	927	822	753
Full Simulation Period Average	1,279	1,299	1,386	1,496	1,623	1,745	1,864	1,788	1,704	1,589	1,442	1,320
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	1,655	1,654	1,705	1,741	1,931	2,052	2,231	2,183	2,096	2,000	1,872	1,744
Above Normal (14%)	1,488	1,516	1,580	1,682	1,848	2,011	2,172	2,084	1,999	1,876	1,689	1,537
Below Normal (18%)	1,254	1,284	1,378	1,555	1,659	1,791	1,917	1,814	1,743	1,605	1,419	1,289
Dry (24%)	1,058	1,097	1,241	1,376	1,487	1,614	1,700	1,594	1,500	1,355	1,194	1,083
Critically Dry (16%)	760	770	842	1,012	1,053	1,114	1,146	1,074	1,014	943	854	784
Full Simulation Period Average	1,280	1,300	1,387	1,495	1,623	1,744	1,865	1,784	1,703	1,588	1,439	1,321
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	-4	-5	-23	-14	-10	-7	-11	-9	-8	-7	-1
Above Normal (14%)	-7	-2	-1	21	11	7	7	5	6	-4	-13	-9
Below Normal (18%)	-9	-11	-14	20	19	18	17	-3	3	3	-13	-9
Dry (24%)	-2	-3	-3	-8	-4	-5	-7	-12	-13	-9	-5	-6
Critically Dry (16%)	33	33	33	8	3	-10	5	10	19	16	32	31
Full Simulation Period Average	1	1	0	-1	0	-1	1	-4	-1	-2	-2	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-179. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir storage for the No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	1,656	1,658	1,709	1,764	1,945	2,061	2,239	2,194	2,105	2,008	1,879	1,745
Above Normal (14%)	1,496	1,518	1,581	1,661	1,837	2,005	2,165	2,079	1,992	1,880	1,702	1,546
Below Normal (18%)	1,263	1,295	1,392	1,536	1,640	1,773	1,900	1,817	1,740	1,602	1,432	1,298
Dry (24%)	1,060	1,100	1,244	1,385	1,492	1,619	1,706	1,606	1,513	1,364	1,199	1,088
Critically Dry (16%)	727	737	810	1,004	1,051	1,123	1,140	1,064	995	927	822	753
Full Simulation Period Average	1,279	1,299	1,386	1,496	1,623	1,745	1,864	1,788	1,704	1,589	1,442	1,320
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	1,655	1,654	1,705	1,741	1,931	2,052	2,231	2,183	2,096	2,000	1,872	1,744
Above Normal (14%)	1,484	1,512	1,575	1,670	1,839	2,003	2,163	2,075	1,990	1,868	1,682	1,532
Below Normal (18%)	1,238	1,270	1,365	1,535	1,640	1,771	1,896	1,793	1,721	1,583	1,399	1,272
Dry (24%)	1,056	1,095	1,239	1,373	1,484	1,611	1,697	1,591	1,498	1,353	1,193	1,082
Critically Dry (16%)	737	747	819	1,009	1,050	1,111	1,129	1,051	994	927	831	762
Full Simulation Period Average	1,273	1,293	1,380	1,489	1,618	1,738	1,857	1,775	1,694	1,580	1,431	1,313
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-2	-4	-5	-23	-14	-10	-7	-11	-9	-8	-7	-1
Above Normal (14%)	-12	-7	-5	9	2	-2	-2	-4	-2	-12	-20	-14
Below Normal (18%)	-24	-25	-27	0	0	-2	-4	-24	-19	-18	-33	-26
Dry (24%)	-4	-4	-5	-11	-7	-8	-9	-14	-15	-11	-6	-7
Critically Dry (16%)	10	10	10	5	-1	-12	-12	-13	-1	0	9	9
Full Simulation Period Average	-6	-6	-7	-7	-6	-7	-7	-14	-10	-10	-11	-7

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-180. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir storage for the No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,656	1,658	1,709	1,764	1,945	2,061	2,239	2,194	2,105	2,008	1,879	1,745
Above Normal (14%)	1,496	1,518	1,581	1,661	1,837	2,005	2,165	2,079	1,992	1,880	1,702	1,546
Below Normal (18%)	1,263	1,295	1,392	1,536	1,640	1,773	1,900	1,817	1,740	1,602	1,432	1,298
Dry (24%)	1,060	1,100	1,244	1,385	1,492	1,619	1,706	1,606	1,513	1,364	1,199	1,088
Critically Dry (16%)	727	737	810	1,004	1,051	1,123	1,140	1,064	995	927	822	753
Full Simulation Period Average	1,279	1,299	1,386	1,496	1,623	1,745	1,864	1,788	1,704	1,589	1,442	1,320
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	1,657	1,655	1,706	1,743	1,933	2,053	2,233	2,185	2,097	2,003	1,874	1,746
Above Normal (14%)	1,482	1,511	1,575	1,660	1,833	2,002	2,163	2,075	1,990	1,871	1,681	1,530
Below Normal (18%)	1,226	1,257	1,354	1,535	1,639	1,771	1,896	1,788	1,717	1,577	1,392	1,261
Dry (24%)	1,057	1,097	1,240	1,367	1,477	1,604	1,690	1,586	1,496	1,350	1,192	1,083
Critically Dry (16%)	738	748	821	1,016	1,065	1,127	1,143	1,065	1,005	934	836	763
Full Simulation Period Average	1,271	1,292	1,378	1,488	1,618	1,739	1,858	1,775	1,695	1,580	1,431	1,312
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	-2	-3	-21	-12	-8	-6	-9	-8	-5	-5	0
Above Normal (14%)	-14	-7	-6	-1	-3	-3	-2	-4	-2	-9	-20	-16
Below Normal (18%)	-37	-38	-38	-1	0	-2	-4	-29	-24	-25	-40	-37
Dry (24%)	-3	-3	-5	-17	-15	-15	-16	-20	-17	-13	-6	-5
Critically Dry (16%)	11	11	11	12	14	3	3	1	10	7	14	11
Full Simulation Period Average	-8	-8	-8	-8	-5	-6	-6	-13	-9	-9	-11	-8

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-181. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir Storage for the No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,656	1,658	1,709	1,764	1,945	2,061	2,239	2,194	2,105	2,008	1,879	1,745
Above Normal (14%)	1,496	1,518	1,581	1,661	1,837	2,005	2,165	2,079	1,992	1,880	1,702	1,546
Below Normal (18%)	1,263	1,295	1,392	1,536	1,640	1,773	1,900	1,817	1,740	1,602	1,432	1,298
Dry (24%)	1,060	1,100	1,244	1,385	1,492	1,619	1,706	1,606	1,513	1,364	1,199	1,088
Critically Dry (16%)	727	737	810	1,004	1,051	1,123	1,140	1,064	995	927	822	753
Full Simulation Period Average	1,279	1,299	1,386	1,496	1,623	1,745	1,864	1,788	1,704	1,589	1,442	1,320
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	1,656	1,656	1,706	1,744	1,933	2,053	2,232	2,183	2,096	2,002	1,873	1,745
Above Normal (14%)	1,475	1,506	1,570	1,655	1,824	1,993	2,154	2,064	1,974	1,857	1,669	1,522
Below Normal (18%)	1,223	1,253	1,350	1,540	1,645	1,776	1,901	1,786	1,713	1,574	1,387	1,259
Dry (24%)	1,074	1,113	1,257	1,376	1,487	1,614	1,701	1,597	1,508	1,366	1,210	1,101
Critically Dry (16%)	734	744	816	1,014	1,055	1,117	1,132	1,056	999	932	828	759
Full Simulation Period Average	1,273	1,294	1,380	1,490	1,618	1,739	1,858	1,774	1,693	1,581	1,430	1,314
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	-2	-3	-21	-12	-9	-6	-11	-9	-6	-7	0
Above Normal (14%)	-20	-12	-10	-6	-12	-12	-11	-15	-18	-23	-33	-25
Below Normal (18%)	-40	-42	-42	4	5	3	1	-31	-28	-27	-45	-39
Dry (24%)	14	13	12	-9	-5	-5	-6	-9	-5	2	11	12
Critically Dry (16%)	7	7	7	10	5	-6	-9	-8	4	5	6	6
Full Simulation Period Average	-6	-6	-6	-6	-5	-6	-6	-14	-11	-8	-11	-7

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

O.5.2 Sacramento River

Under all the action alternatives, flows in the upper Sacramento River result from controlled releases from Shasta Reservoir and Keswick Dam, as well as transfers from the Trinity River and natural accretions. The releases and transfers are determined by a suite of laws, regulations, contracts, and agreements to address demands of water users, requirements for water quality, and needs of fish populations throughout the river and the Delta. In particular, operations of all the action alternatives are regulated by the Water Board's D-1641 decision, which requires flow releases to meet Delta standards, and their WRO 90-5 decision, which requires coldwater releases to meet water temperature targets at compliance points in the upper Sacramento River. Dry hydrologic conditions often lead to inadequate storage in Shasta Reservoir for operators to provide suitable conditions for salmonids and other native species in the upper Sacramento River. In most cases, however, water temperature rather than flow is the limiting factor creating unsuitable conditions, as discussed below. Flow releases are high during the summer to satisfy downstream demands of water users and Delta water quality, and to meet water temperature requirements of incubating Winter-run Chinook salmon eggs and alevins downstream of Keswick Dam.

Alternative 2 (Multi-Agency Consensus) represents actions and tradeoffs made to reach consensus among Reclamation, CDFW, DWR, NMFS, and USFWS. Reclamation will operate minimum instream flows under Alternative 2 in response to major storm events.

After coordination through the Sacramento River Group and Shasta Reservoir Operations Team, and through Adaptive Management, Reclamation may determine that lower flows achieve the same biological effects as the minimum flow of 3,250 cfs at Keswick Dam. If these flows are determined to meet the same biological intent, Reclamation may temporarily reduce flows below 3,250 cfs to preserve storage while meeting the same intent as the minimum flow of 3,250 cfs.

To increase outmigration survival of Chinook salmon, Reclamation would release up to 150 thousand acre feet (TAF) in pulse flow(s) each water year under Alternative 2, typically in the spring, to benefit Chinook salmon in the Sacramento River watershed when the pulse does not interfere with the ability to meet water temperature objectives or other anticipated operations of the reservoir. Alternative 2 includes advancing up to 100 TAF in releases from Shasta Reservoir for a spring-pulse in consideration of actions by Sacramento River Settlement Contractors to make the water available later in the year.

Under Alternative 2, Reclamation is proposing to change the balance between risks of flood control releases for Shasta Reservoir and place a higher priority on maintaining storage for drought protection. The framework establishes management "Bins" to manage water temperature and storage to meet the Objectives described in Chapter 3, Section 3.4.1.7, *Water Temperature and Storage Management.*

Under a circumstance where conditions may cause water temperatures to rise to concerning levels prior to the final Temperature Management Plan, Reclamation will begin water temperature management as early as March 1 to target water temperatures of 58.0° F daily average at the Sacramento River above Clear Creek gage (CCR). Another key component of Alternative 2 includes baseflows in the Fall and Winter for Refill of Shasta Reservoir and Redd Maintenance. For more details on the December through February release schedule, see Chapter 3, Table 3.4-1 under Section 3.4.1.2*, Fall and Winter Baseflows for Shasta Refill and Redd Maintenance*.

O.5.2.1 Sacramento River Flows below Keswick Dam

CalSim 3 modeling suggests that average flows released at Keswick Dam under the four phases of Alternative 2 would be broadly similar (less than a 5% difference) to flows under the No Action Alternative (Table O-182 through Table O-185). Across all four phases of Alternative 2, critically dry years would see decreases in May, June, and August, and increases in November. Alternative 2 without TUCP with systemwide VA would see the greatest amount of flow changes, including increases for most water year types in April and decreases in June for almost every water year type. For all four phases of Alternative 2, the simulation period average is similar to flows under the No Action Alternative, except for April under Alternative 2 without TUCP with systemwide VA.

O.5.2.2 Sacramento River Flows below Red Bluff Diversion Dam

CalSim 3 modeling suggests that average flows in the Sacramento River at Red Bluff Diversion Dam (RBDD) under the four phases of Alternative 2 would be similar (less than a 5% difference) to flows under the No Action Alternative, except under Alternative 2 Without TUCP With Systemwide VA in June (Table O-186 through Table O-189). The largest increases in flows under the four phases of Alternative 2 compared to the No Action Alternative are expected in April of a critically dry water year type. The largest decreases in flows under the four phases of Alternative 2 compared to the No Action Alternative are expected in June of critically dry water years for most phases of Alternative 2.

O.5.2.3 Sacramento River Flows at Wilkins Slough

CalSim 3 modeling suggests that average flows in the Sacramento River at Wilkins Slough under the four phases of Alternative 2 would be similar (less than a 5% difference) to flows under the No Action Alternative (Table O-190 through Table O-193). The largest increases in flows under the four phases of Alternative 2 compared to the No Action Alternative are expected in November and April of a critically dry water year type. The largest decreases in flows under the four phases of Alternative 2 compared to the No Action Alternative are expected in July, August and September of various water year types depending on the phase of Alternative 2.

O.5.2.4 Sacramento River Flows at Hamilton City

CalSim 3 modeling suggests that average flows in the Sacramento River at Hamilton City under the four phases of Alternative 2 would be similar (less than a 5% difference) to flows under the No Action Alternative (Table O-194 through Table O-197). The largest increases in flows under the four phases of Alternative 2 compared to the No Action Alternative are expected in November and April of a critically dry water year type. The largest decreases in flows under the four phases of Alternative 2 compared to the No Action Alternative are expected in June and July in various water year types depending on the phase of Alternative 2.

Table O-182. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,453	6,575	8,760	17,717	23,928	15,969	9,265	7,358	8,719	13,608	10,371	9,177
Above Normal (14%)	6,557	7,216	5,406	10,012	16,075	9,999	5,427	7,925	10,098	15,553	11,005	8,571
Below Normal (18%)	5,525	5,011	7,696	4,912	5,278	5,012	5,325	9,308	10,409	14,159	10,770	5,608
Dry (24%)	4,809	5,025	7,991	3,399	4,693	4,137	5,592	8,051	10,950	13,138	9,106	5,524
Critically Dry (16%)	4,333	4,288	3,335	3,568	4,277	3,662	3,905	7,013	9,415	10,109	7,723	5,030
Full Simulation Period Average	5,869	5,675	7,067	8,633	11,711	8,352	6,279	7,899	9,863	13,307	9,804	6,909
Alternative 2 With TUCP WITHOUT VA												
Wet (28%)	7,514	6,607	8,881	18,025	24,175	15,904	9,235	7,355	8,776	13,404	10,298	9,184
Above Normal (14%)	6,978	7,226	5,416	10,311	16,084	10,169	5,393	7,866	10,209	15,436	10,856	8,806
Below Normal (18%)	5,575	5,419	7,800	4,892	5,443	5,036	5,159	9,231	10,556	13,851	10,591	5,976
Dry (24%)	4,904	5,038	8,363	3,649	4,980	4,122	5,565	7,688	10,742	12,758	9,190	5,560
Critically Dry (16%)	4,674	4,925	3,483	3,425	4,072	3,446	4,030	6,120	8,601	8,947	6,793	4,867
Full Simulation Period Average	6,032	5,857	7,233	8,795	11,847	8,324	6,250	7,646	9,741	12,901	9,602	6,993
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	60	32	121	308	247	-65	-30	-3	57	-204	-73	7
Above Normal (14%)	**421**	10	10	299	9	171	-34	-59	111	-117	-149	235
Below Normal (18%)	50	**408**	104	-19	165	24	-166	-77	148	-309	-180	**368**
Dry (24%)	95	12	372	**250**	**286**	-15	-27	-363	-208	-380	84	36
Critically Dry (16%)	**342**	**637**	148	-143	-205	**-216**	125	**-893**	**-814**	**-1,162**	**-930**	-163
Full Simulation Period Average	163	182	165	162	136	-28	-30	-253	-122	-406	-202	84

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-183. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,453	6,575	8,760	17,717	23,928	15,969	9,265	7,358	8,719	13,608	10,371	9,177
Above Normal (14%)	6,557	7,216	5,406	10,012	16,075	9,999	5,427	7,925	10,098	15,553	11,005	8,571
Below Normal (18%)	5,525	5,011	7,696	4,912	5,278	5,012	5,325	9,308	10,409	14,159	10,770	5,608
Dry (24%)	4,809	5,025	7,991	3,399	4,693	4,137	5,592	8,051	10,950	13,138	9,106	5,524
Critically Dry (16%)	4,333	4,288	3,335	3,568	4,277	3,662	3,905	7,013	9,415	10,109	7,723	5,030
Full Simulation Period Average	5,869	5,675	7,067	8,633	11,711	8,352	6,279	7,899	9,863	13,307	9,804	6,909
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	7,513	6,612	8,872	18,020	24,174	15,904	9,235	7,358	8,779	13,405	10,298	9,185
Above Normal (14%)	6,971	7,239	5,405	9,904	16,022	9,615	5,393	7,866	10,211	15,436	10,831	8,776
Below Normal (18%)	5,538	5,345	7,811	4,890	5,442	5,036	5,160	9,157	10,522	13,641	10,457	5,904
Dry (24%)	4,899	5,033	8,380	3,652	4,845	4,131	5,541	7,679	10,734	12,781	9,184	5,555
Critically Dry (16%)	4,325	4,941	3,355	3,582	4,168	3,994	4,890	6,321	8,753	10,001	6,805	4,519
Full Simulation Period Average	5,971	5,848	7,215	8,762	11,821	8,336	6,382	7,664	9,758	13,037	9,575	6,920
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	60	37	111	303	246	-65	-29	0	60	-203	-74	8
Above Normal (14%)	**414**	22	-1	-108	-53	-384	-34	-59	113	-117	-174	205
Below Normal (18%)	13	**334**	115	-21	164	24	-165	-151	113	-518	-314	**296**
Dry (24%)	90	8	389	**253**	151	-6	-51	-371	-216	-357	78	31
Critically Dry (16%)	-7	**653**	21	14	-109	**332**	**985**	**-692**	**-661**	-107	**-918**	**-510**
Full Simulation Period Average	102	174	148	129	110	-16	103	-235	-105	-269	-230	10

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-184. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,453	6,575	8,760	17,717	23,928	15,969	9,265	7,358	8,719	13,608	10,371	9,177
Above Normal (14%)	6,557	7,216	5,406	10,012	16,075	9,999	5,427	7,925	10,098	15,553	11,005	8,571
Below Normal (18%)	5,525	5,011	7,696	4,912	5,278	5,012	5,325	9,308	10,409	14,159	10,770	5,608
Dry (24%)	4,809	5,025	7,991	3,399	4,693	4,137	5,592	8,051	10,950	13,138	9,106	5,524
Critically Dry (16%)	4,333	4,288	3,335	3,568	4,277	3,662	3,905	7,013	9,415	10,109	7,723	5,030
Full Simulation Period Average	5,869	5,675	7,067	8,633	11,711	8,352	6,279	7,899	9,863	13,307	9,804	6,909
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	7,514	6,692	8,767	17,784	24,176	15,907	9,236	7,340	8,788	13,418	10,330	9,213
Above Normal (14%)	6,999	7,392	5,377	9,882	16,081	9,725	5,379	7,898	10,065	15,534	10,874	8,821
Below Normal (18%)	5,663	5,275	7,852	4,881	5,552	5,038	5,191	9,121	10,508	13,676	10,596	5,826
Dry (24%)	4,902	4,994	8,351	3,491	4,837	4,091	5,391	7,747	10,774	12,933	9,230	5,527
Critically Dry (16%)	4,406	4,919	3,363	3,405	3,618	4,220	5,086	6,341	8,814	10,120	6,915	4,489
Full Simulation Period Average	6,011	5,869	7,183	8,624	11,760	8,379	6,381	7,677	9,757	13,117	9,644	6,908
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	61	118	6	66	248	-61	-29	-18	69	-190	-41	36
Above Normal (14%)	**442**	176	-30	-130	6	-273	-48	-27	-32	-18	-131	250
Below Normal (18%)	138	**265**	156	-31	**274**	26	-135	-186	99	-483	-175	218
Dry (24%)	92	-32	360	92	144	-47	-201	-304	-176	-205	124	2
Critically Dry (16%)	73	**631**	28	-162	**-660**	**558**	**1,181**	**-672**	**-601**	11	**-809**	**-541**
Full Simulation Period Average	141	194	116	-9	48	27	101	-223	-106	-190	-161	-2

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-185. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	7,453	6,575	8,760	17,717	23,928	15,969	9,265	7,358	8,719	13,608	10,371	9,177
Above Normal (14%)	6,557	7,216	5,406	10,012	16,075	9,999	5,427	7,925	10,098	15,553	11,005	8,571
Below Normal (18%)	5,525	5,011	7,696	4,912	5,278	5,012	5,325	9,308	10,409	14,159	10,770	5,608
Dry (24%)	4,809	5,025	7,991	3,399	4,693	4,137	5,592	8,051	10,950	13,138	9,106	5,524
Critically Dry (16%)	4,333	4,288	3,335	3,568	4,277	3,662	3,905	7,013	9,415	10,109	7,723	5,030
Full Simulation Period Average	5,869	5,675	7,067	8,633	11,711	8,352	6,279	7,899	9,863	13,307	9,804	6,909
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	7,495	6,687	8,774	17,993	24,205	15,907	9,326	7,353	8,703	13,402	10,315	9,229
Above Normal (14%)	6,894	7,428	5,398	9,943	16,167	9,390	6,067	8,062	9,391	15,346	10,667	8,844
Below Normal (18%)	5,547	5,330	7,862	4,893	5,584	5,036	5,871	9,281	9,823	13,463	10,420	5,918
Dry (24%)	4,847	5,141	8,565	3,485	4,988	4,116	5,503	7,466	10,285	12,674	9,081	5,548
Critically Dry (16%)	4,393	4,782	3,333	3,825	4,217	3,986	4,989	6,588	8,743	10,101	7,123	4,461
Full Simulation Period Average	5,954	5,897	7,237	8,759	11,918	8,301	6,636	7,704	9,387	12,982	9,576	6,933
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	42	112	14	276	277	-61	61	-5	-17	-205	-57	52
Above Normal (14%)	**337**	211	-8	-69	92	**-609**	**640**	136	**-707**	-206	-338	273
Below Normal (18%)	22	**319**	166	-19	**306**	24	**546**	-27	**-586**	-696	-351	**310**
Dry (24%)	38	115	**573**	86	**295**	-21	-89	**-585**	**-664**	-464	-25	23
Critically Dry (16%)	61	**493**	-2	**258**	-60	**324**	**1,084**	**-425**	**-672**	-8	**-600**	**-568**
Full Simulation Period Average	84	222	170	126	206	-51	**357**	-195	-476	-324	-228	23

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-186. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,228	8,683	13,701	29,751	36,916	25,296	15,001	9,396	9,243	12,998	9,757	9,264
Above Normal (14%)	7,428	9,038	10,730	19,185	26,409	17,672	9,071	9,166	10,002	14,637	10,364	8,607
Below Normal (18%)	6,469	6,914	13,860	10,404	10,259	9,322	7,698	10,248	10,293	13,473	10,270	5,856
Dry (24%)	5,710	6,807	13,495	6,375	10,498	8,387	7,311	8,682	10,748	12,483	8,649	5,677
Critically Dry (16%)	4,793	5,342	6,988	5,988	7,268	5,869	4,836	7,539	9,555	10,051	7,595	5,321
Full Simulation Period Average	6,672	7,466	12,227	15,377	19,563	14,187	9,384	9,049	9,949	12,718	9,322	7,067
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	8,254	8,737	13,890	30,139	37,081	25,300	15,006	9,459	9,204	12,754	9,649	9,252
Above Normal (14%)	7,815	9,069	10,808	19,560	26,341	17,911	9,074	9,169	10,008	14,475	10,178	8,824
Below Normal (18%)	6,487	7,348	14,041	10,469	10,370	9,418	7,582	10,252	10,363	13,152	10,077	6,217
Dry (24%)	5,783	6,838	13,932	6,707	10,799	8,433	7,338	8,441	10,499	12,119	8,744	5,728
Critically Dry (16%)	5,165	5,983	7,133	5,903	7,101	5,679	4,999	6,890	8,818	9,021	6,777	5,191
Full Simulation Period Average	6,814	7,668	12,451	15,616	19,665	14,219	9,398	8,906	9,774	12,317	9,123	7,150
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	26	54	189	389	165	4	5	63	-39	-244	-108	-12
Above Normal (14%)	**387**	31	77	375	-68	239	3	3	6	-162	-186	217
Below Normal (18%)	19	**435**	181	65	111	96	-115	4	70	-322	-193	**361**
Dry (24%)	73	31	438	**331**	301	46	28	-241	-248	-364	95	51
Critically Dry (16%)	**373**	**641**	145	-86	-167	-190	163	**-649**	**-737**	**-1,030**	**-817**	-129
Full Simulation Period Average	142	202	224	239	102	33	14	-143	-175	-401	-199	83

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-187. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,228	8,683	13,701	29,751	36,916	25,296	15,001	9,396	9,243	12,998	9,757	9,264
Above Normal (14%)	7,428	9,038	10,730	19,185	26,409	17,672	9,071	9,166	10,002	14,637	10,364	8,607
Below Normal (18%)	6,469	6,914	13,860	10,404	10,259	9,322	7,698	10,248	10,293	13,473	10,270	5,856
Dry (24%)	5,710	6,807	13,495	6,375	10,498	8,387	7,311	8,682	10,748	12,483	8,649	5,677
Critically Dry (16%)	4,793	5,342	6,988	5,988	7,268	5,869	4,836	7,539	9,555	10,051	7,595	5,321
Full Simulation Period Average	6,672	7,466	12,227	15,377	19,563	14,187	9,384	9,049	9,949	12,718	9,322	7,067
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	8,253	8,742	13,880	30,134	37,079	25,299	15,006	9,461	9,207	12,754	9,648	9,253
Above Normal (14%)	7,807	9,080	10,797	19,160	26,279	17,362	9,073	9,167	10,009	14,474	10,153	8,793
Below Normal (18%)	6,455	7,264	14,039	10,463	10,366	9,416	7,594	10,201	10,357	12,974	9,971	6,154
Dry (24%)	5,780	6,833	13,950	6,710	10,666	8,441	7,318	8,438	10,501	12,151	8,745	5,727
Critically Dry (16%)	4,833	5,999	7,006	6,060	7,196	6,220	5,846	7,098	8,983	10,077	6,817	4,872
Full Simulation Period Average	6,756	7,657	12,432	15,583	19,638	14,230	9,531	8,929	9,801	12,461	9,107	7,084
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	25	59	180	383	164	3	5	65	-37	-244	-109	-11
Above Normal (14%)	**379**	42	66	-25	-130	-310	2	1	7	-163	-211	186
Below Normal (18%)	-14	**350**	179	59	108	95	-104	-47	64	-499	-299	**298**
Dry (24%)	70	27	455	**335**	168	54	7	-244	-247	-333	96	50
Critically Dry (16%)	40	**657**	18	72	-72	**351**	**1,011**	**-441**	**-572**	26	**-778**	**-448**
Full Simulation Period Average	84	191	204	206	76	44	146	-119	-148	-257	-215	17

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-188. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,228	8,683	13,701	29,751	36,916	25,296	15,001	9,396	9,243	12,998	9,757	9,264
Above Normal (14%)	7,428	9,038	10,730	19,185	26,409	17,672	9,071	9,166	10,002	14,637	10,364	8,607
Below Normal (18%)	6,469	6,914	13,860	10,404	10,259	9,322	7,698	10,248	10,293	13,473	10,270	5,856
Dry (24%)	5,710	6,807	13,495	6,375	10,498	8,387	7,311	8,682	10,748	12,483	8,649	5,677
Critically Dry (16%)	4,793	5,342	6,988	5,988	7,268	5,869	4,836	7,539	9,555	10,051	7,595	5,321
Full Simulation Period Average	6,672	7,466	12,227	15,377	19,563	14,187	9,384	9,049	9,949	12,718	9,322	7,067
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	8,255	8,822	13,776	29,900	37,080	25,301	15,006	9,443	9,215	12,767	9,681	9,281
Above Normal (14%)	7,837	9,234	10,769	19,138	26,337	17,472	9,061	9,198	9,864	14,571	10,194	8,837
Below Normal (18%)	6,582	7,195	14,080	10,454	10,474	9,419	7,629	10,176	10,351	13,017	10,116	6,090
Dry (24%)	5,781	6,795	13,921	6,549	10,658	8,400	7,171	8,503	10,530	12,296	8,786	5,697
Critically Dry (16%)	4,905	5,978	7,013	5,880	6,656	6,441	6,026	7,101	9,014	10,165	6,905	4,834
Full Simulation Period Average	6,795	7,678	12,400	15,446	19,578	14,272	9,529	8,940	9,794	12,535	9,172	7,073
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	27	139	75	149	164	5	5	47	-28	-231	-76	17
Above Normal (14%)	**409**	196	39	-47	-72	-200	-10	32	-138	-66	-170	230
Below Normal (18%)	113	281	220	50	215	97	-69	-72	58	-456	-154	234
Dry (24%)	71	-12	426	174	160	13	-140	-179	-218	-187	137	20
Critically Dry (16%)	112	**636**	25	-108	**-612**	**572**	**1,190**	**-438**	**-541**	114	**-690**	**-487**
Full Simulation Period Average	123	212	173	69	15	85	145	-109	-155	-183	-150	6

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-189. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,228	8,683	13,701	29,751	36,916	25,296	15,001	9,396	9,243	12,998	9,757	9,264
Above Normal (14%)	7,428	9,038	10,730	19,185	26,409	17,672	9,071	9,166	10,002	14,637	10,364	8,607
Below Normal (18%)	6,469	6,914	13,860	10,404	10,259	9,322	7,698	10,248	10,293	13,473	10,270	5,856
Dry (24%)	5,710	6,807	13,495	6,375	10,498	8,387	7,311	8,682	10,748	12,483	8,649	5,677
Critically Dry (16%)	4,793	5,342	6,988	5,988	7,268	5,869	4,836	7,539	9,555	10,051	7,595	5,321
Full Simulation Period Average	6,672	7,466	12,227	15,377	19,563	14,187	9,384	9,049	9,949	12,718	9,322	7,067
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	8,236	8,817	13,783	30,107	37,110	25,302	15,098	9,457	9,130	12,751	9,664	9,297
Above Normal (14%)	7,732	9,269	10,790	19,199	26,422	17,140	9,751	9,367	9,195	14,382	9,987	8,860
Below Normal (18%)	6,465	7,246	14,089	10,466	10,506	9,417	8,306	10,330	9,657	12,788	9,928	6,174
Dry (24%)	5,726	6,940	14,133	6,543	10,808	8,426	7,283	8,221	10,038	12,028	8,631	5,712
Critically Dry (16%)	4,903	5,841	6,982	6,298	7,246	6,213	5,949	7,368	8,971	10,169	7,128	4,815
Full Simulation Period Average	6,739	7,705	12,453	15,580	19,734	14,196	9,787	8,971	9,426	12,399	9,103	7,096
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	8	134	82	356	194	6	97	61	-113	-247	-93	33
Above Normal (14%)	304	231	60	14	13	-532	**680**	201	**-807**	-255	-377	253
Below Normal (18%)	-4	332	229	62	247	95	**608**	82	**-636**	**-685**	-342	**318**
Dry (24%)	16	133	638	168	310	39	-28	**-461**	**-710**	-455	-18	35
Critically Dry (16%)	110	**499**	-6	**310**	-22	**344**	**1,113**	-171	**-584**	118	**-467**	**-506**
Full Simulation Period Average	67	239	226	203	171	9	403	-78	**-523**	-319	-219	29

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-190. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	6,747	7,468	10,397	18,705	19,917	17,996	14,436	7,416	5,607	7,544	5,925	7,204
Above Normal (14%)	5,961	7,038	9,668	15,284	18,028	16,281	11,131	6,025	5,489	8,795	6,524	6,581
Below Normal (18%)	4,873	5,672	11,096	10,852	11,463	11,209	8,152	5,869	5,299	7,459	6,026	3,788
Dry (24%)	4,113	5,375	9,640	7,139	11,119	10,068	6,993	4,676	5,632	6,501	4,502	3,592
Critically Dry (16%)	2,894	3,464	6,820	6,285	8,177	7,026	3,957	3,317	4,791	4,776	3,949	3,168
Full Simulation Period Average	5,082	5,977	9,695	12,049	14,141	12,876	9,379	5,629	5,410	7,011	5,369	4,989
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	6,758	7,536	10,545	18,778	19,920	18,002	14,437	7,471	5,576	7,316	5,800	7,163
Above Normal (14%)	6,340	7,042	9,720	15,317	18,012	16,312	11,135	6,032	5,470	8,649	6,357	6,780
Below Normal (18%)	4,895	6,075	11,224	10,902	11,479	11,274	8,049	5,817	5,338	7,163	5,825	4,103
Dry (24%)	4,171	5,370	9,856	7,450	11,178	10,113	7,020	4,476	5,373	6,160	4,575	3,626
Critically Dry (16%)	3,299	3,975	6,980	6,213	7,983	6,834	4,212	3,383	4,760	4,545	3,689	3,271
Full Simulation Period Average	5,221	6,145	9,843	12,147	14,125	12,874	9,409	5,599	5,339	6,754	5,251	5,087
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	11	68	148	73	3	6	1	55	-31	-228	-125	-41
Above Normal (14%)	**379**	4	52	33	-16	31	4	7	-19	-146	-167	199
Below Normal (18%)	22	**403**	128	50	16	65	-103	-52	39	-296	-201	**315**
Dry (24%)	58	-5	216	311	59	45	27	-200	-259	**-341**	73	34
Critically Dry (16%)	**405**	**511**	160	-72	-194	-192	**255**	66	-31	-231	**-260**	103
Full Simulation Period Average	139	168	148	98	-16	-2	30	-30	-71	-257	-118	98

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-191. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	6,747	7,468	10,397	18,705	19,917	17,996	14,436	7,416	5,607	7,544	5,925	7,204
Above Normal (14%)	5,961	7,038	9,668	15,284	18,028	16,281	11,131	6,025	5,489	8,795	6,524	6,581
Below Normal (18%)	4,873	5,672	11,096	10,852	11,463	11,209	8,152	5,869	5,299	7,459	6,026	3,788
Dry (24%)	4,113	5,375	9,640	7,139	11,119	10,068	6,993	4,676	5,632	6,501	4,502	3,592
Critically Dry (16%)	2,894	3,464	6,820	6,285	8,177	7,026	3,957	3,317	4,791	4,776	3,949	3,168
Full Simulation Period Average	5,082	5,977	9,695	12,049	14,141	12,876	9,379	5,629	5,410	7,011	5,369	4,989
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	6,756	7,539	10,535	18,773	19,919	18,001	14,436	7,472	5,577	7,315	5,800	7,162
Above Normal (14%)	6,331	7,048	9,721	15,274	18,005	16,208	11,118	6,030	5,471	8,646	6,336	6,744
Below Normal (18%)	4,854	6,008	11,215	10,892	11,472	11,271	8,056	5,766	5,331	6,990	5,724	4,034
Dry (24%)	4,166	5,366	9,865	7,448	11,163	10,116	6,999	4,471	5,370	6,187	4,577	3,623
Critically Dry (16%)	3,057	3,990	6,874	6,373	8,072	7,316	4,978	3,637	4,950	5,538	3,802	3,028
Full Simulation Period Average	5,174	6,136	9,825	12,163	14,134	12,937	9,525	5,629	5,368	6,888	5,248	5,030
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	9	71	138	68	2	5	0	56	-30	-229	-125	-42
Above Normal (14%)	**370**	10	53	-10	-23	-73	-13	5	-18	-149	-188	163
Below Normal (18%)	-19	**336**	119	40	9	62	-96	-103	32	**-469**	**-302**	**246**
Dry (24%)	53	-9	225	309	44	48	6	-205	-262	-314	75	31
Critically Dry (16%)	**163**	**526**	54	88	-105	290	**1,021**	**320**	159	**762**	-147	-140
Full Simulation Period Average	92	159	130	114	-7	61	146	0	-42	-123	-121	41

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-192. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	6,747	7,468	10,397	18,705	19,917	17,996	14,436	7,416	5,607	7,544	5,925	7,204
Above Normal (14%)	5,961	7,038	9,668	15,284	18,028	16,281	11,131	6,025	5,489	8,795	6,524	6,581
Below Normal (18%)	4,873	5,672	11,096	10,852	11,463	11,209	8,152	5,869	5,299	7,459	6,026	3,788
Dry (24%)	4,113	5,375	9,640	7,139	11,119	10,068	6,993	4,676	5,632	6,501	4,502	3,592
Critically Dry (16%)	2,894	3,464	6,820	6,285	8,177	7,026	3,957	3,317	4,791	4,776	3,949	3,168
Full Simulation Period Average	5,082	5,977	9,695	12,049	14,141	12,876	9,379	5,629	5,410	7,011	5,369	4,989
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	6,753	7,595	10,472	18,740	19,918	18,001	14,428	7,436	5,563	7,322	5,824	7,176
Above Normal (14%)	6,358	7,226	9,701	15,262	18,011	16,236	11,104	6,030	5,330	8,732	6,366	6,773
Below Normal (18%)	4,973	5,937	11,267	10,883	11,532	11,275	8,074	5,738	5,318	7,030	5,861	3,970
Dry (24%)	4,158	5,349	9,855	7,291	11,168	10,096	6,858	4,490	5,390	6,325	4,625	3,595
Critically Dry (16%)	3,115	3,954	6,857	6,179	7,780	7,501	5,119	3,636	4,978	5,623	3,888	3,008
Full Simulation Period Average	5,205	6,156	9,809	12,081	14,099	12,966	9,513	5,619	5,351	6,956	5,309	5,016
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	6	127	75	35	1	5	-8	20	-44	-222	-101	-28
Above Normal (14%)	**397**	188	33	-22	-17	-45	-27	5	-159	-63	-158	192
Below Normal (18%)	100	265	171	31	69	66	-78	-131	19	**-429**	-165	182
Dry (24%)	45	-26	215	152	49	28	-135	-186	-242	-176	123	3
Critically Dry (16%)	**221**	**490**	37	-106	-397	**475**	**1,162**	**319**	187	**847**	-61	**-160**
Full Simulation Period Average	123	179	114	32	-42	90	134	-10	-59	-55	-60	27

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-193. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	6,747	7,468	10,397	18,705	19,917	17,996	14,436	7,416	5,607	7,544	5,925	7,204
Above Normal (14%)	5,961	7,038	9,668	15,284	18,028	16,281	11,131	6,025	5,489	8,795	6,524	6,581
Below Normal (18%)	4,873	5,672	11,096	10,852	11,463	11,209	8,152	5,869	5,299	7,459	6,026	3,788
Dry (24%)	4,113	5,375	9,640	7,139	11,119	10,068	6,993	4,676	5,632	6,501	4,502	3,592
Critically Dry (16%)	2,894	3,464	6,820	6,285	8,177	7,026	3,957	3,317	4,791	4,776	3,949	3,168
Full Simulation Period Average	5,082	5,977	9,695	12,049	14,141	12,876	9,379	5,629	5,410	7,011	5,369	4,989
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	6,746	7,602	10,485	18,767	19,920	18,000	14,469	7,487	5,531	7,352	5,840	7,196
Above Normal (14%)	6,312	7,252	9,744	15,290	18,019	16,144	11,787	6,480	4,999	8,842	6,367	6,811
Below Normal (18%)	4,928	6,001	11,297	10,893	11,545	11,274	8,793	6,174	5,005	7,122	5,897	4,062
Dry (24%)	4,169	5,491	9,937	7,285	11,214	10,108	7,016	4,481	5,229	6,364	4,683	3,627
Critically Dry (16%)	3,127	3,817	6,842	6,571	8,132	7,315	5,095	3,891	4,955	5,640	4,110	3,002
Full Simulation Period Average	5,192	6,187	9,842	12,156	14,171	12,926	9,783	5,813	5,197	7,008	5,369	5,050
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	134	88	62	3	4	33	71	-76	-192	-85	-8
Above Normal (14%)	**351**	214	76	6	-9	-137	**656**	**455**	**-490**	47	-157	230
Below Normal (18%)	55	**329**	201	41	82	65	**641**	**305**	**-294**	-337	-129	**274**
Dry (24%)	56	116	297	146	95	40	23	-195	**-403**	-137	181	35
Critically Dry (16%)	**233**	**353**	22	286	-45	289	**1,138**	**574**	164	**864**	161	**-166**
Full Simulation Period Average	110	210	147	107	30	50	404	184	-213	-3	0	61

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-194. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,774	9,060	15,844	36,160	43,468	29,725	17,650	8,737	7,593	10,522	8,015	8,486
Above Normal (14%)	7,022	9,205	13,122	23,971	31,918	21,265	10,557	7,853	7,987	12,017	8,577	7,776
Below Normal (18%)	6,086	7,165	17,022	13,255	12,647	11,442	8,573	8,564	8,090	10,753	8,376	5,047
Dry (24%)	5,424	6,996	15,816	7,835	13,272	10,306	7,768	6,767	8,428	9,720	6,726	4,808
Critically Dry (16%)	4,248	5,011	8,610	7,004	8,624	6,911	4,760	5,640	7,496	7,846	6,133	4,536
Full Simulation Period Average	6,264	7,638	14,556	18,868	23,481	16,939	10,589	7,614	7,923	10,152	7,548	6,253
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	7,797	9,113	16,031	36,545	43,630	29,727	17,652	8,797	7,554	10,279	7,907	8,471
Above Normal (14%)	7,407	9,235	13,197	24,343	31,850	21,501	10,559	7,856	7,991	11,856	8,392	7,990
Below Normal (18%)	6,102	7,595	17,201	13,319	12,757	11,536	8,459	8,568	8,158	10,434	8,182	5,401
Dry (24%)	5,494	7,024	16,251	8,164	13,569	10,349	7,794	6,530	8,179	9,359	6,819	4,856
Critically Dry (16%)	4,671	5,610	8,766	6,918	8,458	6,724	4,993	5,429	7,189	7,264	5,653	4,588
Full Simulation Period Average	6,412	7,831	14,780	19,104	23,582	16,970	10,613	7,541	7,815	9,824	7,403	6,362
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	23	53	187	385	162	2	2	60	-39	-243	-108	-15
Above Normal (14%)	**385**	30	75	372	-68	236	2	3	4	-161	-185	214
Below Normal (18%)	16	**430**	179	64	110	94	-114	4	68	-319	-194	**354**
Dry (24%)	70	28	435	329	297	43	26	-237	-249	-361	93	48
Critically Dry (16%)	**423**	**599**	156	-86	-166	-187	233	-211	-307	**-582**	**-480**	52
Full Simulation Period Average	148	193	224	236	101	31	24	-73	-108	-328	-145	109

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-195. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,774	9,060	15,844	36,160	43,468	29,725	17,650	8,737	7,593	10,522	8,015	8,486
Above Normal (14%)	7,022	9,205	13,122	23,971	31,918	21,265	10,557	7,853	7,987	12,017	8,577	7,776
Below Normal (18%)	6,086	7,165	17,022	13,255	12,647	11,442	8,573	8,564	8,090	10,753	8,376	5,047
Dry (24%)	5,424	6,996	15,816	7,835	13,272	10,306	7,768	6,767	8,428	9,720	6,726	4,808
Critically Dry (16%)	4,248	5,011	8,610	7,004	8,624	6,911	4,760	5,640	7,496	7,846	6,133	4,536
Full Simulation Period Average	6,264	7,638	14,556	18,868	23,481	16,939	10,589	7,614	7,923	10,152	7,548	6,253
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	7,795	9,117	16,021	36,538	43,628	29,725	17,650	8,799	7,555	10,279	7,906	8,471
Above Normal (14%)	7,399	9,246	13,186	23,946	31,788	20,955	10,557	7,854	7,991	11,854	8,368	7,958
Below Normal (18%)	6,069	7,510	17,198	13,311	12,752	11,533	8,469	8,516	8,152	10,256	8,077	5,339
Dry (24%)	5,491	7,019	16,268	8,167	13,436	10,356	7,773	6,527	8,180	9,390	6,821	4,856
Critically Dry (16%)	4,393	5,640	8,640	7,077	8,552	7,256	5,826	5,645	7,363	8,320	5,699	4,303
Full Simulation Period Average	6,362	7,822	14,760	19,072	23,555	16,979	10,742	7,566	7,843	9,968	7,388	6,301
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	21	57	177	378	160	0	0	62	-38	-243	-109	-15
Above Normal (14%)	**377**	41	64	-25	-130	-310	0	1	4	-163	-209	182
Below Normal (18%)	-17	345	176	56	105	91	-104	-48	62	-497	-299	**292**
Dry (24%)	67	23	452	332	164	50	5	-240	-248	-330	95	48
Critically Dry (16%)	145	**629**	30	73	-72	345	**1,066**	5	-133	**474**	**-434**	**-233**
Full Simulation Period Average	98	184	204	204	74	40	153	-48	-80	-184	-160	48

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-196. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,774	9,060	15,844	36,160	43,468	29,725	17,650	8,737	7,593	10,522	8,015	8,486
Above Normal (14%)	7,022	9,205	13,122	23,971	31,918	21,265	10,557	7,853	7,987	12,017	8,577	7,776
Below Normal (18%)	6,086	7,165	17,022	13,255	12,647	11,442	8,573	8,564	8,090	10,753	8,376	5,047
Dry (24%)	5,424	6,996	15,816	7,835	13,272	10,306	7,768	6,767	8,428	9,720	6,726	4,808
Critically Dry (16%)	4,248	5,011	8,610	7,004	8,624	6,911	4,760	5,640	7,496	7,846	6,133	4,536
Full Simulation Period Average	6,264	7,638	14,556	18,868	23,481	16,939	10,589	7,614	7,923	10,152	7,548	6,253
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	7,798	9,198	15,918	36,307	43,629	29,728	17,651	8,782	7,563	10,292	7,938	8,499
Above Normal (14%)	7,430	9,400	13,158	23,924	31,846	21,064	10,545	7,884	7,848	11,950	8,408	8,002
Below Normal (18%)	6,197	7,441	17,239	13,302	12,859	11,536	8,504	8,493	8,146	10,299	8,222	5,275
Dry (24%)	5,492	6,981	16,239	8,006	13,429	10,316	7,629	6,591	8,208	9,533	6,862	4,826
Critically Dry (16%)	4,463	5,618	8,646	6,893	8,020	7,474	5,988	5,648	7,393	8,406	5,786	4,274
Full Simulation Period Average	6,401	7,843	14,728	18,934	23,495	17,021	10,738	7,577	7,836	10,042	7,452	6,292
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	24	138	74	147	161	3	1	45	-30	-230	-77	13
Above Normal (14%)	**408**	195	36	-47	-72	-201	-12	31	-139	-67	-169	226
Below Normal (18%)	111	276	217	47	212	94	-69	-71	56	-454	-154	228
Dry (24%)	68	-15	423	171	157	10	-139	-176	-220	-187	136	18
Critically Dry (16%)	**215**	**607**	36	-111	**-604**	**563**	**1,228**	8	-103	**560**	**-347**	**-262**
Full Simulation Period Average	137	205	172	66	14	82	149	-37	-87	-110	-96	39

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-197. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,774	9,060	15,844	36,160	43,468	29,725	17,650	8,737	7,593	10,522	8,015	8,486
Above Normal (14%)	7,022	9,205	13,122	23,971	31,918	21,265	10,557	7,853	7,987	12,017	8,577	7,776
Below Normal (18%)	6,086	7,165	17,022	13,255	12,647	11,442	8,573	8,564	8,090	10,753	8,376	5,047
Dry (24%)	5,424	6,996	15,816	7,835	13,272	10,306	7,768	6,767	8,428	9,720	6,726	4,808
Critically Dry (16%)	4,248	5,011	8,610	7,004	8,624	6,911	4,760	5,640	7,496	7,846	6,133	4,536
Full Simulation Period Average	6,264	7,638	14,556	18,868	23,481	16,939	10,589	7,614	7,923	10,152	7,548	6,253
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	7,784	9,198	15,928	36,497	43,659	29,729	17,742	8,815	7,507	10,308	7,942	8,506
Above Normal (14%)	7,353	9,465	13,208	23,966	31,931	20,736	11,252	8,185	7,376	11,970	8,332	7,968
Below Normal (18%)	6,116	7,527	17,281	13,302	12,891	11,535	9,204	8,791	7,670	10,297	8,179	5,295
Dry (24%)	5,473	7,157	16,480	7,985	13,577	10,342	7,768	6,446	7,919	9,475	6,841	4,785
Critically Dry (16%)	4,469	5,487	8,618	7,298	8,602	7,250	5,933	5,920	7,362	8,420	6,015	4,259
Full Simulation Period Average	6,367	7,891	14,799	19,053	23,650	16,945	11,013	7,691	7,594	10,037	7,467	6,280
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	10	138	84	337	191	4	92	78	-86	-214	-73	20
Above Normal (14%)	331	260	86	-5	13	-529	**695**	332	**-611**	-47	-245	192
Below Normal (18%)	30	**362**	259	47	244	93	**631**	227	**-420**	-456	-197	248
Dry (24%)	49	161	664	150	305	36	0	-321	**-509**	-245	115	-23
Critically Dry (16%)	**221**	**476**	8	294	-22	339	**1,173**	280	-134	**574**	-118	**-277**
Full Simulation Period Average	103	253	243	185	169	6	424	77	-329	-115	-81	27

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

O.5.3 Bay-Delta

O.5.3.1 Delta X2

CalSim 3 modeling indicates that the estimated X2 position under Alternative 2 when compared to the No Action Alternative is similar across all months and water year types. (Table O-198 through Table O-201). Table O-198 through Table O-201 indicate that most landward X2 positions are expected during the summer to fall months in the critically dry years and the most seaward positions are expected during the winter to early spring months in wet years for both alternatives. For the full simulation period, there were either no or small differences in X2 position between all Alternative 2 phases and the No Action Alternative for all months.

O.5.3.2 Delta Exports

CalSim 3 modeling indicates that the total exports of the SWP and CVP under Alternative 2 when compared to the No Action Alternative generally increases in May and decreases in June for all phases and most water year types. For the phases without VAs, exports also increase during April. During the dry and critically dry water years type exports tend to decrease in the winter for all phases. Also during drier years, the phases that included VA agreements tend to have increased exports in the summer whereas for the phases without VA agreements exports tend to decrease during the same season (Table O-202 through Table O-205). For the full simulation period, total exports when compared to the No Action Alternative increase from April and May for the phases without VAs and increase only in May for the phases with VAs. For phases without VAs, exports decrease in June, while for the phases with VAs, exports decrease in March and June.

O.5.3.3 Delta Outflow

CalSim3 modeling indicates that delta outflow under Alternative 2 compared to the No Action Alternative was generally similar except for April or May, depending on the phase (Table O 206 through Table O 209). Some water year types are expected to see flow increases in winter and spring months, as well as June seeing flow increases in certain year types depending on the phase. Flow decreases are expected in some summer and spring months depending on water year type and phase, with May, July, and August having notable decreases in most phases of Alternative 2 during wet, above normal, and below normal water years.

O.5.3.4 Delta OMR

CalSim 3 modeling indicates that average Old and Middle River (OMR) combined flows under Alternative 2 when compared to the No Action Alternative are dissimilar, varying significantly (more than 5% difference) from flow values under the No Action Alternative (Table O 210 through Table O 213) for many months of the year. Values are expected to see increases in all water year types and in all phases for the month of May, as well as for the month of April for phases of Alternative 2 without VA. June is expected to see decreases for almost all water year types across all phases. The period January through June sees the greatest difference between the phases of Alternative 2 and the No Action Alternative. January and February are expected to see decreases in dry and critically dry water years for all phases of Alternative 2. Phases with VA are expected to see flow decreases for most water year types in March.

O.5.3.5 Sacramento River flow at Rio Vista

CalSim 3 modeling indicates that average flows in the Sacramento River at Rio Vista under the four phases of Alternative 2 compared to the No Action Alternative are similar, except in April under Alternative 2 without TUCP with Systemwide VA (Table O-214 through Table O-217). Critically dry water years are expected to see mostly increases from March through July. Under Alternative 2 without TUCP with systemwide VA April is expected to see significant (greater than 5%) flow increases for almost all water year types. Across all four phases of Alternative 2 there are few significant flow decreases scattered across water year types. Average flows across all phases are not significantly different than those under the No Action Alternative, with the exception of April under Alternative 2 without TUCP with Systemwide VA.

Table O-198. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	X2 Position (km)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	79	80	74	56	54	55	58	63	72	78	83	79
Above Normal (14%)	80	83	77	62	57	57	62	69	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	68	72	80	83	87	90
Dry (24%)	91	88	78	79	69	68	72	77	82	86	89	92
Critically Dry (16%)	94	93	85	82	77	77	83	87	89	92	93	93
Full Simulation Period Average	86	86	77	69	64	64	68	73	79	83	87	86
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	79	80	74	56	54	55	58	64	72	79	83	79
Above Normal (14%)	80	84	77	62	57	57	63	70	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	68	74	80	83	86	90
Dry (24%)	91	88	78	78	68	68	72	78	82	86	90	92
Critically Dry (16%)	94	93	85	82	77	77	82	87	89	92	93	93
Full Simulation Period Average	86	86	77	69	63	64	68	73	79	83	87	86
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	0	0	0	0	0	1	0	0	0	0
Above Normal (14%)	0	0	0	0	0	0	1	1	0	0	0	0
Below Normal (18%)	0	0	0	0	0	0	1	1	0	0	0	0
Dry (24%)	0	0	0	-1	-1	0	0	1	0	0	0	0
Critically Dry (16%)	0	0	-1	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	0	0	0	0	0	0	0	1	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses.

Table O-199. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	X2 Position (km)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	79	80	74	56	54	55	58	63	72	78	83	79
Above Normal (14%)	80	83	77	62	57	57	62	69	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	68	72	80	83	87	90
Dry (24%)	91	88	78	79	69	68	72	77	82	86	89	92
Critically Dry (16%)	94	93	85	82	77	77	83	87	89	92	93	93
Full Simulation Period Average	86	86	77	69	64	64	68	73	79	83	87	86
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	79	80	74	56	54	55	58	64	72	79	83	79
Above Normal (14%)	80	84	77	62	57	57	63	70	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	69	74	80	83	87	90
Dry (24%)	91	88	78	78	68	68	72	78	82	86	90	92
Critically Dry (16%)	94	92	85	82	77	76	80	85	87	90	92	93
Full Simulation Period Average	86	86	77	69	63	63	67	73	79	83	87	87
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	0	0	0	0	0	1	0	0	0	0
Above Normal (14%)	0	0	0	0	0	0	1	1	0	0	0	0
Below Normal (18%)	0	0	0	0	0	0	1	1	0	0	0	0
Dry (24%)	0	0	0	-1	-1	0	0	1	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	-1	-3	-2	-2	-2	-1	0
Full Simulation Period Average	0	0	0	0	0	0	0	0	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses.

Table O-200. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	X2 Position (km)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	79	80	74	56	54	55	58	63	72	78	83	79
Above Normal (14%)	80	83	77	62	57	57	62	69	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	68	72	80	83	87	90
Dry (24%)	91	88	78	79	69	68	72	77	82	86	89	92
Critically Dry (16%)	94	93	85	82	77	77	83	87	89	92	93	93
Full Simulation Period Average	86	86	77	69	64	64	68	73	79	83	87	86
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	79	80	74	56	54	55	58	64	72	78	83	79
Above Normal (14%)	80	84	77	62	57	57	62	69	77	80	83	80
Below Normal (18%)	90	89	74	70	66	63	67	74	80	83	87	90
Dry (24%)	91	88	78	79	69	67	71	77	82	86	90	92
Critically Dry (16%)	94	92	85	82	77	76	79	85	87	90	92	93
Full Simulation Period Average	86	86	77	69	64	63	67	73	79	83	87	87
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	0	0	0	0	0	1	0	0	0	0
Above Normal (14%)	0	0	0	0	0	0	0	1	0	0	0	0
Below Normal (18%)	0	0	0	0	0	-1	0	1	0	0	0	0
Dry (24%)	0	0	0	-1	0	-1	0	0	0	0	0	0
Critically Dry (16%)	0	-1	0	0	1	-1	-3	-2	-2	-2	-1	0
Full Simulation Period Average	0	0	0	0	0	-1	-1	0	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses.

Table O-201. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	X2 Position (km)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	79	80	74	56	54	55	58	63	72	78	83	79
Above Normal (14%)	80	83	77	62	57	57	62	69	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	68	72	80	83	87	90
Dry (24%)	91	88	78	79	69	68	72	77	82	86	89	92
Critically Dry (16%)	94	93	85	82	77	77	83	87	89	92	93	93
Full Simulation Period Average	86	86	77	69	64	64	68	73	79	83	87	86
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	79	80	74	56	54	55	58	63	72	78	83	79
Above Normal (14%)	80	84	77	62	57	57	61	68	77	79	83	80
Below Normal (18%)	90	89	74	70	66	63	66	72	80	83	86	90
Dry (24%)	91	88	78	79	68	67	70	76	82	86	89	92
Critically Dry (16%)	94	92	85	82	76	75	79	84	87	90	92	93
Full Simulation Period Average	86	86	77	69	63	63	66	72	79	83	87	87
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	0	0	0	0	0	1	0	0	0	0
Above Normal (14%)	0	0	0	0	0	0	-1	-1	0	0	0	0
Below Normal (18%)	0	0	0	0	0	-1	-2	-1	0	0	-1	0
Dry (24%)	0	0	0	-1	-1	-1	-2	-1	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	-2	-4	-3	-3	-2	-1	0
Full Simulation Period Average	0	0	0	0	0	-1	-2	-1	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses.

Table O-202. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,586	10,782	8,504	9,217	9,986	8,557	7,132	6,750	7,386	10,597	10,891	8,364
Above Normal (14%)	5,987	10,099	8,039	7,441	8,282	6,935	4,259	4,336	5,864	10,356	10,686	5,703
Below Normal (18%)	5,887	7,526	7,027	6,408	7,112	6,214	3,808	3,669	5,502	9,913	8,767	6,714
Dry (24%)	4,225	6,067	5,475	6,216	6,321	5,760	3,082	2,916	4,929	7,138	4,116	5,320
Critically Dry (16%)	2,715	2,579	5,724	5,078	5,559	4,421	2,045	2,124	1,895	1,631	1,637	2,660
Full Simulation Period Average	5,503	7,732	7,024	7,080	7,642	6,575	4,345	4,197	5,365	8,175	7,373	6,051
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	7,583	10,752	8,603	9,143	10,306	9,398	8,013	8,566	7,284	10,472	10,854	8,464
Above Normal (14%)	5,822	10,084	8,036	7,307	8,536	7,098	5,786	5,667	5,416	10,766	10,956	6,283
Below Normal (18%)	5,637	7,646	7,024	6,242	6,916	6,199	4,764	4,663	5,001	10,137	9,001	7,098
Dry (24%)	4,200	6,052	5,574	5,718	5,886	5,637	3,514	3,458	4,378	6,781	4,138	5,269
Critically Dry (16%)	2,803	2,824	5,636	4,791	5,359	4,166	2,265	2,378	1,790	1,518	1,425	2,681
Full Simulation Period Average	5,440	7,775	7,062	6,845	7,596	6,761	5,117	5,242	5,035	8,134	7,414	6,221
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-4	-30	99	-74	321	**841**	**881**	**1,816**	-102	-125	-37	100
Above Normal (14%)	-165	-16	-3	-134	255	163	**1,527**	**1,331**	**-448**	410	270	**580**
Below Normal (18%)	-250	120	-3	-166	-196	-14	**956**	**993**	**-501**	224	234	**383**
Dry (24%)	-25	-15	99	**-498**	**-435**	-123	**432**	**542**	**-551**	**-357**	22	-51
Critically Dry (16%)	88	**245**	-88	**-287**	-200	**-255**	**220**	**254**	**-105**	**-113**	**-211**	21
Full Simulation Period Average	-64	44	37	-235	-46	185	**772**	**1,044**	**-330**	-41	41	169

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-203. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,586	10,782	8,504	9,217	9,986	8,557	7,132	6,750	7,386	10,597	10,891	8,364
Above Normal (14%)	5,987	10,099	8,039	7,441	8,282	6,935	4,259	4,336	5,864	10,356	10,686	5,703
Below Normal (18%)	5,887	7,526	7,027	6,408	7,112	6,214	3,808	3,669	5,502	9,913	8,767	6,714
Dry (24%)	4,225	6,067	5,475	6,216	6,321	5,760	3,082	2,916	4,929	7,138	4,116	5,320
Critically Dry (16%)	2,715	2,579	5,724	5,078	5,559	4,421	2,045	2,124	1,895	1,631	1,637	2,660
Full Simulation Period Average	5,503	7,732	7,024	7,080	7,642	6,575	4,345	4,197	5,365	8,175	7,373	6,051
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	7,577	10,754	8,597	9,134	10,302	9,339	8,036	8,554	7,283	10,466	10,858	8,453
Above Normal (14%)	5,823	10,103	8,032	7,295	8,472	7,053	5,780	5,666	5,415	10,767	10,875	6,268
Below Normal (18%)	5,540	7,639	6,955	6,239	6,878	6,199	4,766	4,592	4,982	9,955	8,595	6,997
Dry (24%)	4,198	6,036	5,501	5,720	5,885	5,637	3,513	3,456	4,377	6,713	4,105	5,268
Critically Dry (16%)	2,554	2,537	5,753	4,702	5,272	3,675	2,513	2,361	1,811	1,826	1,419	3,019
Full Simulation Period Average	5,383	7,731	7,047	6,827	7,565	6,659	5,162	5,222	5,034	8,133	7,322	6,251
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-9	-28	93	-83	316	**782**	**904**	**1,804**	-103	-131	-33	89
Above Normal (14%)	-164	4	-7	-146	191	118	**1,521**	**1,330**	**-448**	411	189	**564**
Below Normal (18%)	**-347**	113	-72	-170	-234	-14	**958**	**923**	**-520**	42	-173	283
Dry (24%)	-27	-31	27	**-496**	**-436**	-124	**431**	**540**	**-552**	**-425**	-11	-51
Critically Dry (16%)	**-161**	-43	29	**-375**	**-287**	**-746**	**468**	**237**	-84	**195**	**-218**	**359**
Full Simulation Period Average	-120	-1	23	-253	-77	84	**817**	**1,025**	**-331**	-42	-51	200

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-204. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	7,586	10,782	8,504	9,217	9,986	8,557	7,132	6,750	7,386	10,597	10,891	8,364
Above Normal (14%)	5,987	10,099	8,039	7,441	8,282	6,935	4,259	4,336	5,864	10,356	10,686	5,703
Below Normal (18%)	5,887	7,526	7,027	6,408	7,112	6,214	3,808	3,669	5,502	9,913	8,767	6,714
Dry (24%)	4,225	6,067	5,475	6,216	6,321	5,760	3,082	2,916	4,929	7,138	4,116	5,320
Critically Dry (16%)	2,715	2,579	5,724	5,078	5,559	4,421	2,045	2,124	1,895	1,631	1,637	2,660
Full Simulation Period Average	5,503	7,732	7,024	7,080	7,642	6,575	4,345	4,197	5,365	8,175	7,373	6,051
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	7,567	10,928	8,422	9,125	10,291	9,019	6,994	8,549	7,279	10,428	10,862	8,584
Above Normal (14%)	5,801	10,330	8,013	7,296	8,476	5,558	3,545	5,290	5,398	10,656	10,863	6,574
Below Normal (18%)	5,774	7,738	7,037	6,225	6,860	4,252	3,827	4,435	5,050	9,899	9,331	6,888
Dry (24%)	4,238	5,925	5,572	5,817	5,907	4,553	2,801	3,149	4,292	7,262	4,847	5,196
Critically Dry (16%)	2,618	2,404	6,112	4,661	5,282	3,707	2,480	2,374	1,896	2,532	1,752	3,029
Full Simulation Period Average	5,438	7,785	7,081	6,839	7,566	5,755	4,213	5,068	5,037	8,342	7,685	6,295
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-19	146	-82	-92	305	**462**	-138	**1,799**	-107	-169	-29	219
Above Normal (14%)	-186	231	-25	-145	194	**-1,377**	**-714**	**954**	**-465**	301	178	**871**
Below Normal (18%)	-113	212	10	-183	-252	**-1,961**	19	**766**	**-452**	-14	**563**	174
Dry (24%)	13	-142	97	**-399**	**-414**	**-1,208**	**-281**	**233**	**-637**	124	**731**	-124
Critically Dry (16%)	-97	**-175**	**388**	**-417**	-277	**-714**	**435**	**250**	2	**901**	**115**	**369**
Full Simulation Period Average	-65	53	57	-241	-76	**-821**	-133	**871**	**-329**	166	312	244

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-205. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	7,586	10,782	8,504	9,217	9,986	8,557	7,132	6,750	7,386	10,597	10,891	8,364
Above Normal (14%)	5,987	10,099	8,039	7,441	8,282	6,935	4,259	4,336	5,864	10,356	10,686	5,703
Below Normal (18%)	5,887	7,526	7,027	6,408	7,112	6,214	3,808	3,669	5,502	9,913	8,767	6,714
Dry (24%)	4,225	6,067	5,475	6,216	6,321	5,760	3,082	2,916	4,929	7,138	4,116	5,320
Critically Dry (16%)	2,715	2,579	5,724	5,078	5,559	4,421	2,045	2,124	1,895	1,631	1,637	2,660
Full Simulation Period Average	5,503	7,732	7,024	7,080	7,642	6,575	4,345	4,197	5,365	8,175	7,373	6,051
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	7,703	10,926	8,418	9,127	10,293	9,002	6,997	8,567	7,283	10,430	10,865	8,494
Above Normal (14%)	5,934	10,329	7,990	7,306	8,405	5,602	3,552	5,242	5,392	10,609	10,843	6,491
Below Normal (18%)	5,697	7,778	6,987	6,226	6,855	4,253	3,795	4,493	5,042	9,937	9,307	7,055
Dry (24%)	4,241	6,041	5,646	5,762	5,904	4,560	2,802	3,076	4,288	7,185	4,885	5,210
Critically Dry (16%)	2,699	2,407	5,796	4,673	5,244	3,553	2,512	2,379	1,819	2,465	1,809	3,037
Full Simulation Period Average	5,495	7,820	7,038	6,830	7,548	5,733	4,214	5,060	5,022	8,313	7,697	6,293
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	117	143	-86	-90	307	**445**	-135	**1,817**	-102	-167	-26	130
Above Normal (14%)	-53	229	-48	-135	124	**-1,334**	**-706**	**906**	**-471**	254	158	**787**
Below Normal (18%)	-190	252	-40	-182	-257	**-1,960**	-13	**824**	**-461**	24	**540**	**341**
Dry (24%)	16	-26	171	**-454**	**-418**	**-1,201**	**-279**	**161**	**-641**	47	**769**	-109
Critically Dry (16%)	-16	**-172**	72	**-405**	**-315**	**-868**	**467**	**255**	-76	**834**	**172**	**376**
Full Simulation Period Average	-8	88	13	-251	-94	**-842**	-131	**863**	**-344**	138	324	242

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-206. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,918	12,055	30,736	96,898	122,709	90,897	54,587	31,188	13,556	9,410	6,009	11,294
Above Normal (14%)	8,664	7,873	21,249	53,164	71,004	58,493	27,859	17,453	9,163	10,682	6,287	10,956
Below Normal (18%)	5,366	6,747	30,789	25,764	29,373	26,423	19,249	15,376	7,772	8,121	4,144	3,679
Dry (24%)	5,887	9,013	30,407	13,571	27,568	19,839	14,134	10,846	7,191	5,232	3,826	3,213
Critically Dry (16%)	3,094	5,758	11,444	10,903	15,095	10,560	6,745	5,961	4,141	3,217	3,030	3,554
Full Simulation Period Average	6,640	8,798	26,350	44,213	58,618	44,847	27,121	17,500	8,866	7,363	4,712	6,698
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	8,900	12,106	30,713	97,505	122,658	90,045	53,559	29,429	13,793	9,093	5,841	11,221
Above Normal (14%)	9,234	7,884	21,155	53,978	70,648	58,389	25,793	16,159	9,639	9,752	5,907	11,212
Below Normal (18%)	5,459	7,027	31,110	25,931	29,970	26,614	18,136	14,001	8,227	7,562	4,203	3,655
Dry (24%)	5,825	8,929	30,883	14,246	28,267	19,930	13,715	10,357	7,214	5,015	3,611	3,232
Critically Dry (16%)	3,096	5,867	12,030	11,002	14,979	10,481	6,887	5,912	4,357	3,260	3,030	3,506
Full Simulation Period Average	6,722	8,860	26,589	44,705	58,810	44,638	26,266	16,454	9,121	6,998	4,570	6,706
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-18	50	-23	607	-51	-852	-1,027	**-1,759**	238	-317	-169	-73
Above Normal (14%)	**570**	12	-94	814	-356	-104	**-2,066**	**-1,294**	**476**	**-930**	**-380**	256
Below Normal (18%)	92	281	321	167	597	191	**-1,113**	**-1,375**	**455**	**-559**	59	-24
Dry (24%)	-62	-84	477	675	699	91	-419	-488	23	-218	**-215**	19
Critically Dry (16%)	2	110	**586**	98	-116	-79	142	-49	**216**	42	0	-48
Full Simulation Period Average	82	63	239	492	192	-210	-855	**-1,046**	255	-365	-142	8

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-207. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,918	12,055	30,736	96,898	122,709	90,897	54,587	31,188	13,556	9,410	6,009	11,294
Above Normal (14%)	8,664	7,873	21,249	53,164	71,004	58,493	27,859	17,453	9,163	10,682	6,287	10,956
Below Normal (18%)	5,366	6,747	30,789	25,764	29,373	26,423	19,249	15,376	7,772	8,121	4,144	3,679
Dry (24%)	5,887	9,013	30,407	13,571	27,568	19,839	14,134	10,846	7,191	5,232	3,826	3,213
Critically Dry (16%)	3,094	5,758	11,444	10,903	15,095	10,560	6,745	5,961	4,141	3,217	3,030	3,554
Full Simulation Period Average	6,640	8,798	26,350	44,213	58,618	44,847	27,121	17,500	8,866	7,363	4,712	6,698
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	8,900	12,107	30,703	97,475	122,623	90,057	53,536	29,413	13,792	9,103	5,838	11,220
Above Normal (14%)	9,233	7,892	21,145	53,515	70,624	57,677	25,751	16,149	9,636	9,755	5,907	11,212
Below Normal (18%)	5,491	6,929	31,161	25,748	29,827	26,592	18,045	14,004	8,230	7,444	4,187	3,610
Dry (24%)	5,811	8,933	30,966	14,251	28,122	19,935	13,712	10,348	7,214	5,015	3,611	3,230
Critically Dry (16%)	3,251	6,257	11,384	11,397	15,123	11,975	8,916	5,999	5,256	4,000	3,015	3,000
Full Simulation Period Average	6,747	8,903	26,517	44,663	58,759	44,778	26,561	16,461	9,264	7,098	4,564	6,616
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-19	52	-33	577	-87	-841	-1,051	**-1,775**	236	-307	-171	-74
Above Normal (14%)	**569**	19	-104	351	-381	-816	**-2,108**	**-1,303**	**473**	**-927**	**-380**	256
Below Normal (18%)	124	183	372	-17	454	169	**-1,204**	**-1,372**	**458**	**-677**	43	-69
Dry (24%)	-76	-81	559	**680**	554	97	-422	-498	23	-218	**-215**	17
Critically Dry (16%)	**157**	**499**	-60	494	27	**1,415**	**2,171**	38	**1,115**	**783**	-16	**-554**
Full Simulation Period Average	108	106	167	450	142	-70	-560	**-1,040**	399	-265	-148	-82

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-208. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,918	12,055	30,736	96,898	122,709	90,897	54,587	31,188	13,556	9,410	6,009	11,294
Above Normal (14%)	8,664	7,873	21,249	53,164	71,004	58,493	27,859	17,453	9,163	10,682	6,287	10,956
Below Normal (18%)	5,366	6,747	30,789	25,764	29,373	26,423	19,249	15,376	7,772	8,121	4,144	3,679
Dry (24%)	5,887	9,013	30,407	13,571	27,568	19,839	14,134	10,846	7,191	5,232	3,826	3,213
Critically Dry (16%)	3,094	5,758	11,444	10,903	15,095	10,560	6,745	5,961	4,141	3,217	3,030	3,554
Full Simulation Period Average	6,640	8,798	26,350	44,213	58,618	44,847	27,121	17,500	8,866	7,363	4,712	6,698
ALTERNATIVE 2 WITHOUT TUCP WITH DELTA VA												
Wet (28%)	8,892	12,077	30,639	97,017	122,519	90,360	54,574	29,360	13,759	9,191	5,816	11,225
Above Normal (14%)	9,231	7,793	21,137	53,494	70,676	58,834	27,937	16,446	9,425	10,011	5,895	11,231
Below Normal (18%)	5,498	6,889	31,003	25,679	29,718	28,454	18,994	13,860	8,236	7,475	4,225	3,573
Dry (24%)	5,776	8,921	30,773	13,966	28,131	21,045	14,242	10,549	7,184	5,035	3,583	3,286
Critically Dry (16%)	3,161	6,487	10,943	11,032	14,416	12,146	8,894	5,998	5,256	4,000	3,010	3,000
Full Simulation Period Average	6,724	8,905	26,357	44,393	58,607	45,653	27,452	16,510	9,220	7,169	4,556	6,627
ALTERNATIVE 2 WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-26	21	-96	119	-190	-537	-12	**-1,828**	204	-219	-193	-69
Above Normal (14%)	**567**	-79	-111	330	-329	341	77	**-1,006**	262	**-672**	**-392**	276
Below Normal (18%)	132	143	213	-86	345	**2,031**	-255	**-1,516**	**464**	**-646**	81	-106
Dry (24%)	-111	-92	366	395	564	**1,206**	108	-297	-7	-197	**-243**	73
Critically Dry (16%)	67	**729**	-501	129	-679	**1,586**	**2,149**	37	**1,115**	**783**	-20	**-554**
Full Simulation Period Average	85	107	7	180	-11	806	331	**-991**	354	-194	-156	-71

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-209. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,918	12,055	30,736	96,898	122,709	90,897	54,587	31,188	13,556	9,410	6,009	11,294
Above Normal (14%)	8,664	7,873	21,249	53,164	71,004	58,493	27,859	17,453	9,163	10,682	6,287	10,956
Below Normal (18%)	5,366	6,747	30,789	25,764	29,373	26,423	19,249	15,376	7,772	8,121	4,144	3,679
Dry (24%)	5,887	9,013	30,407	13,571	27,568	19,839	14,134	10,846	7,191	5,232	3,826	3,213
Critically Dry (16%)	3,094	5,758	11,444	10,903	15,095	10,560	6,745	5,961	4,141	3,217	3,030	3,554
Full Simulation Period Average	6,640	8,798	26,350	44,213	58,618	44,847	27,121	17,500	8,866	7,363	4,712	6,698
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	8,905	12,046	30,603	97,229	122,585	90,235	54,900	29,499	13,721	9,226	5,835	11,217
Above Normal (14%)	9,236	7,879	21,229	53,971	70,857	58,443	29,979	17,801	9,137	10,268	5,922	11,175
Below Normal (18%)	5,703	6,909	30,986	25,719	29,706	28,666	21,691	14,974	7,807	7,728	4,177	3,648
Dry (24%)	5,816	9,222	31,038	14,022	28,282	21,399	16,010	11,271	7,057	5,026	3,590	3,281
Critically Dry (16%)	3,185	6,267	11,221	11,432	15,176	12,339	9,357	6,494	5,256	4,000	3,016	3,000
Full Simulation Period Average	6,779	8,952	26,463	44,604	58,807	45,718	28,813	17,191	9,061	7,258	4,559	6,629
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-13	-9	-133	332	-124	-663	313	**-1,689**	166	-184	-174	-77
Above Normal (14%)	**572**	6	-20	807	-147	-50	**2,120**	348	-26	-414	**-365**	219
Below Normal (18%)	**337**	163	196	-45	333	**2,243**	**2,442**	-402	36	-392	32	-31
Dry (24%)	-70	209	631	451	715	**1,560**	**1,876**	426	-134	-207	**-236**	68
Critically Dry (16%)	91	**509**	-223	528	81	**1,779**	**2,612**	**533**	**1,115**	**783**	-15	**-554**
Full Simulation Period Average	140	154	113	391	189	870	**1,692**	-309	195	-104	-153	-69

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-210. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	-6,128	-8,400	-5,569	-2,718	-1,706	-1,261	-1,861	-1,095	-4,159	-9,708	-10,116	-7,642
Above Normal (14%)	-4,935	-8,399	-5,963	-4,302	-3,528	-3,169	-1,650	-2,348	-4,778	-10,023	-10,386	-5,854
Below Normal (18%)	-5,152	-6,123	-4,900	-4,312	-4,100	-3,658	-2,060	-2,114	-4,859	-9,847	-9,043	-6,759
Dry (24%)	-3,644	-4,859	-3,704	-4,442	-4,031	-3,933	-2,095	-2,204	-4,796	-8,003	-4,819	-5,490
Critically Dry (16%)	-2,539	-1,982	-4,330	-3,630	-3,692	-3,053	-1,079	-1,748	-2,272	-2,668	-2,463	-3,002
Full Simulation Period Average	-4,639	-6,178	-4,875	-3,786	-3,268	-2,888	-1,798	-1,825	-4,222	-8,241	-7,465	-5,974
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	-6,122	-8,357	-5,652	-2,634	-1,999	-2,068	-2,777	-2,766	-4,081	-9,607	-10,076	-7,803
Above Normal (14%)	-4,790	-8,389	-5,968	-4,235	-3,813	-3,319	-3,505	-3,580	-4,380	-10,363	-10,658	-6,353
Below Normal (18%)	-4,937	-6,227	-4,887	-4,147	-3,896	-3,642	-2,970	-3,065	-4,417	-10,020	-9,357	-7,049
Dry (24%)	-3,617	-4,824	-3,766	-3,989	-3,614	-3,813	-2,503	-2,736	-4,295	-7,689	-4,830	-5,426
Critically Dry (16%)	-2,565	-2,237	-4,250	-3,392	-3,501	-2,822	-1,252	-1,983	-2,136	-2,520	-2,243	-3,010
Full Simulation Period Average	-4,574	-6,212	-4,899	-3,577	-3,222	-3,066	-2,604	-2,801	-3,923	-8,193	-7,516	-6,127
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	6	43	-83	84	**-294**	**-807**	**-916**	**-1,671**	78	101	40	-161
Above Normal (14%)	145	10	-5	67	**-284**	-150	**-1,854**	**-1,231**	**397**	-340	-272	**-499**
Below Normal (18%)	215	-103	13	164	204	17	**-910**	**-951**	**442**	-173	-314	-291
Dry (24%)	27	36	-61	**453**	**417**	121	**-408**	**-531**	**501**	313	-11	64
Critically Dry (16%)	-26	**-255**	80	**238**	**191**	**231**	**-173**	**-235**	**136**	**148**	**220**	-7
Full Simulation Period Average	64	-35	-24	**209**	45	**-178**	**-806**	**-977**	**299**	48	-51	-153

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-211. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	-6,128	-8,400	-5,569	-2,718	-1,706	-1,261	-1,861	-1,095	-4,159	-9,708	-10,116	-7,642
Above Normal (14%)	-4,935	-8,399	-5,963	-4,302	-3,528	-3,169	-1,650	-2,348	-4,778	-10,023	-10,386	-5,854
Below Normal (18%)	-5,152	-6,123	-4,900	-4,312	-4,100	-3,658	-2,060	-2,114	-4,859	-9,847	-9,043	-6,759
Dry (24%)	-3,644	-4,859	-3,704	-4,442	-4,031	-3,933	-2,095	-2,204	-4,796	-8,003	-4,819	-5,490
Critically Dry (16%)	-2,539	-1,982	-4,330	-3,630	-3,692	-3,053	-1,079	-1,748	-2,272	-2,668	-2,463	-3,002
Full Simulation Period Average	-4,639	-6,178	-4,875	-3,786	-3,268	-2,888	-1,798	-1,825	-4,222	-8,241	-7,465	-5,974
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	-6,118	-8,356	-5,648	-2,635	-1,996	-2,021	-2,786	-2,780	-4,080	-9,598	-10,081	-7,801
Above Normal (14%)	-4,786	-8,406	-5,965	-4,235	-3,762	-3,286	-3,504	-3,578	-4,381	-10,361	-10,602	-6,318
Below Normal (18%)	-4,844	-6,200	-4,829	-4,147	-3,855	-3,642	-2,966	-3,003	-4,403	-9,859	-8,956	-6,970
Dry (24%)	-3,620	-4,816	-3,704	-3,989	-3,612	-3,812	-2,504	-2,734	-4,294	-7,625	-4,800	-5,420
Critically Dry (16%)	-2,278	-1,833	-4,337	-3,300	-3,444	-2,398	-1,598	-1,913	-2,106	-3,030	-2,329	-3,401
Full Simulation Period Average	-4,513	-6,147	-4,885	-3,562	-3,197	-2,980	-2,661	-2,782	-3,916	-8,227	-7,443	-6,168
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	10	44	-79	84	**-290**	**-760**	**-925**	**-1,685**	78	110	35	-159
Above Normal (14%)	149	-7	-2	67	**-234**	-117	**-1,854**	**-1,230**	**397**	-338	-216	**-464**
Below Normal (18%)	**308**	-76	71	164	**245**	17	**-906**	**-889**	**456**	-13	87	-212
Dry (24%)	24	43	1	**453**	**419**	121	**-409**	**-530**	**502**	378	19	70
Critically Dry (16%)	**261**	**149**	-6	**330**	**248**	**655**	**-519**	**-165**	**166**	**-362**	**134**	**-399**
Full Simulation Period Average	125	30	-10	**224**	70	-92	**-863**	**-958**	**307**	14	21	-194

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-212. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	-6,128	-8,400	-5,569	-2,718	-1,706	-1,261	-1,861	-1,095	-4,159	-9,708	-10,116	-7,642
Above Normal (14%)	-4,935	-8,399	-5,963	-4,302	-3,528	-3,169	-1,650	-2,348	-4,778	-10,023	-10,386	-5,854
Below Normal (18%)	-5,152	-6,123	-4,900	-4,312	-4,100	-3,658	-2,060	-2,114	-4,859	-9,847	-9,043	-6,759
Dry (24%)	-3,644	-4,859	-3,704	-4,442	-4,031	-3,933	-2,095	-2,204	-4,796	-8,003	-4,819	-5,490
Critically Dry (16%)	-2,539	-1,982	-4,330	-3,630	-3,692	-3,053	-1,079	-1,748	-2,272	-2,668	-2,463	-3,002
Full Simulation Period Average	-4,639	-6,178	-4,875	-3,786	-3,268	-2,888	-1,798	-1,825	-4,222	-8,241	-7,465	-5,974
ALTERNATIVE 2 WITHOUT TUCP WITH DELTA VA												
Wet (28%)	-6,111	-8,528	-5,492	-2,623	-1,989	-1,738	-1,843	-2,779	-4,077	-9,573	-10,098	-7,927
Above Normal (14%)	-4,762	-8,611	-5,948	-4,235	-3,765	-1,925	-1,413	-3,254	-4,368	-10,333	-10,670	-6,654
Below Normal (18%)	-5,061	-6,312	-4,906	-4,132	-3,830	-1,868	-2,086	-2,913	-4,496	-9,902	-9,527	-6,908
Dry (24%)	-3,660	-4,745	-3,779	-4,081	-3,634	-2,844	-1,843	-2,471	-4,242	-8,094	-5,415	-5,336
Critically Dry (16%)	-2,325	-1,700	-4,656	-3,261	-3,442	-2,429	-1,579	-1,930	-2,184	-3,633	-2,591	-3,467
Full Simulation Period Average	-4,563	-6,210	-4,919	-3,572	-3,196	-2,164	-1,784	-2,660	-3,930	-8,433	-7,750	-6,230
ALTERNATIVE 2 WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	17	-128	78	95	**-283**	**-478**	18	**-1,683**	82	135	17	-284
Above Normal (14%)	173	-212	15	67	**-237**	**1,244**	**238**	**-906**	**410**	-310	-284	**-800**
Below Normal (18%)	91	-189	-7	179	**270**	**1,790**	-26	**-799**	**363**	-55	**-484**	-150
Dry (24%)	-17	114	-75	**362**	**397**	**1,090**	**252**	**-266**	**553**	-91	-596	154
Critically Dry (16%)	**214**	**282**	**-326**	**369**	**249**	**624**	**-500**	**-182**	88	**-965**	**-128**	**-465**
Full Simulation Period Average	75	-32	-44	**214**	71	**724**	14	**-835**	**292**	-192	-285	-256

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-213. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	-6,128	-8,400	-5,569	-2,718	-1,706	-1,261	-1,861	-1,095	-4,159	-9,708	-10,116	-7,642
Above Normal (14%)	-4,935	-8,399	-5,963	-4,302	-3,528	-3,169	-1,650	-2,348	-4,778	-10,023	-10,386	-5,854
Below Normal (18%)	-5,152	-6,123	-4,900	-4,312	-4,100	-3,658	-2,060	-2,114	-4,859	-9,847	-9,043	-6,759
Dry (24%)	-3,644	-4,859	-3,704	-4,442	-4,031	-3,933	-2,095	-2,204	-4,796	-8,003	-4,819	-5,490
Critically Dry (16%)	-2,539	-1,982	-4,330	-3,630	-3,692	-3,053	-1,079	-1,748	-2,272	-2,668	-2,463	-3,002
Full Simulation Period Average	-4,639	-6,178	-4,875	-3,786	-3,268	-2,888	-1,798	-1,825	-4,222	-8,241	-7,465	-5,974
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	-6,236	-8,526	-5,488	-2,625	-1,984	-1,663	-1,777	-2,779	-4,079	-9,568	-10,096	-7,840
Above Normal (14%)	-4,890	-8,612	-5,926	-4,235	-3,692	-1,875	-1,311	-3,253	-4,345	-10,267	-10,616	-6,441
Below Normal (18%)	-4,998	-6,354	-4,861	-4,135	-3,830	-1,776	-1,795	-2,974	-4,466	-9,858	-9,529	-7,009
Dry (24%)	-3,659	-4,851	-3,843	-4,028	-3,620	-2,705	-1,562	-2,391	-4,239	-7,925	-5,414	-5,332
Critically Dry (16%)	-2,411	-1,719	-4,371	-3,267	-3,398	-2,212	-1,507	-1,930	-2,112	-3,606	-2,656	-3,455
Full Simulation Period Average	-4,619	-6,245	-4,879	-3,562	-3,174	-2,051	-1,620	-2,651	-3,910	-8,370	-7,753	-6,191
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-109	-126	81	94	**-279**	**-403**	83	**-1,684**	79	139	20	-198
Above Normal (14%)	45	-213	37	67	-163	**1,294**	**339**	**-905**	**433**	-244	-230	**-587**
Below Normal (18%)	153	-230	38	177	**270**	**1,882**	**265**	**-860**	**392**	-12	**-486**	-251
Dry (24%)	-15	8	-139	**414**	**411**	**1,228**	**533**	**-186**	**557**	78	**-595**	158
Critically Dry (16%)	**128**	**263**	-40	**363**	**294**	**840**	**-428**	**-182**	**160**	**-938**	**-193**	**-453**
Full Simulation Period Average	19	-67	-4	**225**	94	**836**	**178**	**-827**	**313**	-129	-288	-217

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-214. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River Flow at Rio Vista for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,929	13,097	29,134	82,363	104,439	73,383	40,479	20,772	9,466	11,109	9,638	11,382
Above Normal (14%)	7,795	10,558	22,225	47,116	62,080	48,912	20,595	13,844	7,846	13,276	10,441	10,213
Below Normal (18%)	6,147	8,224	29,745	23,742	25,296	22,329	14,058	12,234	7,154	11,407	8,272	6,178
Dry (24%)	6,377	9,250	27,844	13,212	25,067	17,799	11,076	9,263	7,324	8,513	5,224	5,046
Critically Dry (16%)	3,621	4,344	12,645	10,561	13,992	9,893	4,748	5,310	3,824	3,870	3,391	3,869
Full Simulation Period Average	6,849	9,603	25,425	38,792	50,742	37,269	20,166	13,029	7,406	9,685	7,446	7,559
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	8,935	13,101	29,183	82,842	104,680	73,385	40,475	20,847	9,588	10,832	9,494	11,434
Above Normal (14%)	8,084	10,568	22,255	47,856	62,041	48,957	20,577	13,915	7,884	12,900	10,398	10,741
Below Normal (18%)	6,054	8,577	30,020	23,713	25,615	22,465	13,989	11,995	7,155	11,170	8,503	6,348
Dry (24%)	6,295	9,172	28,339	13,374	25,356	17,753	11,113	9,359	6,970	8,153	5,103	5,015
Critically Dry (16%)	3,656	4,608	13,076	10,420	13,698	9,594	5,023	5,492	3,872	3,760	3,207	3,837
Full Simulation Period Average	6,863	9,690	25,676	39,041	50,884	37,241	20,203	13,069	7,368	9,408	7,382	7,665
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	6	5	49	479	241	2	-4	75	122	-276	-144	51
Above Normal (14%)	288	10	30	740	-39	46	-18	71	39	-376	-43	**529**
Below Normal (18%)	-93	353	276	-29	319	136	-69	-240	1	-237	232	169
Dry (24%)	-82	-78	496	162	289	-46	36	96	-354	-360	-121	-31
Critically Dry (16%)	35	**264**	431	-141	-294	-300	**275**	181	48	-109	**-185**	-32
Full Simulation Period Average	14	87	251	249	142	-27	37	40	-38	-277	-63	106

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-215. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River Flow at Rio Vista for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,929	13,097	29,134	82,363	104,439	73,383	40,479	20,772	9,466	11,109	9,638	11,382
Above Normal (14%)	7,795	10,558	22,225	47,116	62,080	48,912	20,595	13,844	7,846	13,276	10,441	10,213
Below Normal (18%)	6,147	8,224	29,745	23,742	25,296	22,329	14,058	12,234	7,154	11,407	8,272	6,178
Dry (24%)	6,377	9,250	27,844	13,212	25,067	17,799	11,076	9,263	7,324	8,513	5,224	5,046
Critically Dry (16%)	3,621	4,344	12,645	10,561	13,992	9,893	4,748	5,310	3,824	3,870	3,391	3,869
Full Simulation Period Average	6,849	9,603	25,425	38,792	50,742	37,269	20,166	13,029	7,406	9,685	7,446	7,559
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	8,932	13,102	29,171	82,810	104,640	73,359	40,465	20,844	9,586	10,832	9,496	11,426
Above Normal (14%)	7,908	10,586	22,243	47,437	61,976	48,260	20,541	13,905	7,883	12,901	10,358	10,712
Below Normal (18%)	6,095	8,457	29,998	23,557	25,431	22,442	13,906	11,940	7,148	10,993	8,224	6,265
Dry (24%)	6,294	9,166	28,355	13,376	25,215	17,760	11,110	9,350	6,970	8,114	5,082	5,012
Critically Dry (16%)	3,633	4,583	12,584	10,675	13,751	10,489	7,062	5,570	4,435	4,652	3,247	3,812
Full Simulation Period Average	6,840	9,666	25,597	38,986	50,805	37,277	20,505	13,067	7,457	9,509	7,329	7,640
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	4	5	37	447	201	-24	-13	72	120	-277	-142	44
Above Normal (14%)	113	29	18	321	-104	-652	-54	62	37	-375	-83	500
Below Normal (18%)	-52	233	254	-186	135	113	-152	-294	-7	-413	-47	87
Dry (24%)	-83	-85	511	163	149	-38	34	87	-354	-399	-141	-35
Critically Dry (16%)	12	**239**	-61	114	-241	**595**	**2,314**	259	**611**	**783**	-144	-57
Full Simulation Period Average	-10	63	172	194	63	9	340	38	50	-175	-117	81

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-216. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River Flow at Rio Vista for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,929	13,097	29,134	82,363	104,439	73,383	40,479	20,772	9,466	11,109	9,638	11,382
Above Normal (14%)	7,795	10,558	22,225	47,116	62,080	48,912	20,595	13,844	7,846	13,276	10,441	10,213
Below Normal (18%)	6,147	8,224	29,745	23,742	25,296	22,329	14,058	12,234	7,154	11,407	8,272	6,178
Dry (24%)	6,377	9,250	27,844	13,212	25,067	17,799	11,076	9,263	7,324	8,513	5,224	5,046
Critically Dry (16%)	3,621	4,344	12,645	10,561	13,992	9,893	4,748	5,310	3,824	3,870	3,391	3,869
Full Simulation Period Average	6,849	9,603	25,425	38,792	50,742	37,269	20,166	13,029	7,406	9,685	7,446	7,559
ALTERNATIVE 2 WITHOUT TUCP WITH DELTA VA												
Wet (28%)	8,918	13,211	28,968	82,370	104,538	73,364	40,467	20,800	9,563	10,874	9,492	11,529
Above Normal (14%)	7,887	10,662	22,217	47,431	62,030	47,931	20,444	13,856	7,728	13,049	10,331	10,976
Below Normal (18%)	6,256	8,509	29,926	23,487	25,293	22,345	13,893	11,719	7,206	11,010	8,661	6,203
Dry (24%)	6,289	9,082	28,246	13,216	25,170	17,761	10,933	9,262	6,892	8,432	5,499	4,986
Critically Dry (16%)	3,599	4,594	12,507	10,325	13,139	10,633	7,015	5,578	4,493	5,073	3,421	3,845
Full Simulation Period Average	6,855	9,699	25,485	38,755	50,651	37,238	20,440	12,989	7,430	9,689	7,530	7,693
ALTERNATIVE 2 WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-11	114	-166	6	99	-19	-12	28	97	-234	-146	147
Above Normal (14%)	92	104	-8	315	-49	-980	-150	12	-118	-227	-110	**763**
Below Normal (18%)	109	285	182	-256	-3	16	-165	-515	52	-397	390	24
Dry (24%)	-88	-169	402	4	104	-37	-143	-2	**-432**	-81	**275**	-60
Critically Dry (16%)	-23	**250**	-138	-236	**-853**	**739**	**2,267**	**268**	**669**	**1,204**	30	-24
Full Simulation Period Average	6	96	61	-37	-91	-30	274	-41	23	4	85	134

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-217. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River Flow at Rio Vista for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,929	13,097	29,134	82,363	104,439	73,383	40,479	20,772	9,466	11,109	9,638	11,382
Above Normal (14%)	7,795	10,558	22,225	47,116	62,080	48,912	20,595	13,844	7,846	13,276	10,441	10,213
Below Normal (18%)	6,147	8,224	29,745	23,742	25,296	22,329	14,058	12,234	7,154	11,407	8,272	6,178
Dry (24%)	6,377	9,250	27,844	13,212	25,067	17,799	11,076	9,263	7,324	8,513	5,224	5,046
Critically Dry (16%)	3,621	4,344	12,645	10,561	13,992	9,893	4,748	5,310	3,824	3,870	3,391	3,869
Full Simulation Period Average	6,849	9,603	25,425	38,792	50,742	37,269	20,166	13,029	7,406	9,685	7,446	7,559
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	8,931	13,205	28,960	82,565	104,609	73,145	40,622	20,884	9,543	10,894	9,517	11,472
Above Normal (14%)	7,911	10,769	22,300	47,872	62,160	47,518	22,011	14,969	7,524	13,107	10,311	10,789
Below Normal (18%)	6,400	8,592	29,896	23,529	25,332	22,439	15,892	12,673	6,923	11,060	8,638	6,342
Dry (24%)	6,277	9,425	28,567	13,219	25,387	17,935	12,171	9,787	6,800	8,256	5,496	4,984
Critically Dry (16%)	3,600	4,465	12,483	10,680	13,756	10,614	7,348	6,005	4,458	5,098	3,500	3,853
Full Simulation Period Average	6,886	9,791	25,564	38,937	50,847	37,175	21,413	13,534	7,317	9,673	7,542	7,677
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	3	109	-174	201	170	-238	144	112	76	-214	-121	90
Above Normal (14%)	116	211	75	756	81	-1,394	**1,416**	**1,125**	-322	-169	-130	**577**
Below Normal (18%)	253	368	152	-213	36	111	**1,835**	439	-231	-347	367	164
Dry (24%)	-100	175	723	7	320	136	**1,095**	**524**	**-524**	-257	**272**	-63
Critically Dry (16%)	-21	121	-162	119	-236	**721**	**2,600**	**695**	**635**	**1,228**	109	-16
Full Simulation Period Average	36	189	139	145	104	-94	**1,248**	505	-90	-11	97	118

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

O.5.4 Clear Creek

O.5.4.1 Clear Creek below Whiskeytown Dam

CalSim 3 modeling suggests that average monthly flow below Whiskeytown Dam under the four phases of Alternative 2 compared to the No Action Alternative are expected to generally decrease June through October and February, and generally increase November through January and March through May (Table O-218 through Table O-221). The largest decrease under Alternative 2 compared to the No Action Alternative is expected June through August of all water year types, except critically dry year types when it would be expected in June and September. The largest increases under Alternative 2 compared to the No Action Alternative are expected in December, January, March, and May all water year types, except critically dry year types when it would be expected in January, February, and May.

Table O-218. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	200	200	200	305	494	300	200	200	318	150	150	150
Above Normal (14%)	200	200	200	193	365	200	200	200	318	150	150	150
Below Normal (18%)	200	190	192	194	339	200	200	200	318	150	150	142
Dry (24%)	200	200	200	194	232	192	196	200	318	150	150	150
Critically Dry (16%)	117	100	143	177	169	166	153	150	225	145	141	137
Full Simulation Period Average	187	183	190	222	333	221	192	192	303	149	149	146
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	168	222	270	390	414	369	235	266	221	106	114	135
Above Normal (14%)	168	222	270	275	286	271	235	266	221	106	114	135
Below Normal (18%)	168	221	270	279	286	271	235	266	221	106	114	127
Dry (24%)	168	222	270	277	252	251	228	266	221	106	114	135
Critically Dry (16%)	133	122	141	231	207	188	155	231	143	141	141	129
Full Simulation Period Average	163	207	250	301	301	280	220	261	208	112	119	132
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**-32**	**22**	**70**	**85**	**-80**	**69**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Above Normal (14%)	**-32**	**22**	**70**	**82**	**-79**	**71**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Below Normal (18%)	**-32**	**31**	**78**	**85**	**-53**	**71**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Dry (24%)	**-32**	**22**	**70**	**83**	**20**	**59**	**32**	**66**	**-97**	**-44**	**-36**	**-15**
Critically Dry (16%)	**16**	**22**	-2	**54**	**38**	**22**	2	**81**	**-82**	-4	0	**-8**
Full Simulation Period Average	**-24**	**24**	**60**	**79**	**-32**	**60**	**29**	**69**	**-95**	**-37**	**-30**	**-14**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-219. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	200	200	200	305	494	300	200	200	318	150	150	150
Above Normal (14%)	200	200	200	193	365	200	200	200	318	150	150	150
Below Normal (18%)	200	190	192	194	339	200	200	200	318	150	150	142
Dry (24%)	200	200	200	194	232	192	196	200	318	150	150	150
Critically Dry (16%)	117	100	143	177	169	166	153	150	225	145	141	137
Full Simulation Period Average	187	183	190	222	333	221	192	192	303	149	149	146
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	168	222	270	390	414	369	235	266	221	106	114	135
Above Normal (14%)	168	222	270	275	286	271	235	266	221	106	114	135
Below Normal (18%)	168	210	258	278	286	271	235	266	221	106	114	120
Dry (24%)	168	222	270	277	252	251	228	266	221	106	114	135
Critically Dry (16%)	126	122	142	231	206	188	155	231	150	150	134	124
Full Simulation Period Average	162	205	249	301	301	280	220	261	209	113	118	130
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**-32**	**22**	**70**	**85**	**-80**	**69**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Above Normal (14%)	**-32**	**22**	**70**	**82**	**-79**	**71**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Below Normal (18%)	**-32**	**20**	**66**	**84**	**-53**	**71**	**35**	**66**	**-97**	**-44**	**-36**	**-22**
Dry (24%)	**-32**	**22**	**70**	**83**	**20**	**59**	**32**	**66**	**-97**	**-44**	**-36**	**-15**
Critically Dry (16%)	**9**	**22**	-1	**54**	**37**	**22**	2	**81**	**-75**	5	-7	**-13**
Full Simulation Period Average	**-25**	**22**	**59**	**79**	**-32**	**60**	**29**	**69**	**-94**	**-36**	**-31**	**-16**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-220. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	200	200	200	305	494	300	200	200	318	150	150	150
Above Normal (14%)	200	200	200	193	365	200	200	200	318	150	150	150
Below Normal (18%)	200	190	192	194	339	200	200	200	318	150	150	142
Dry (24%)	200	200	200	194	232	192	196	200	318	150	150	150
Critically Dry (16%)	117	100	143	177	169	166	153	150	225	145	141	137
Full Simulation Period Average	187	183	190	222	333	221	192	192	303	149	149	146
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	168	222	270	390	414	369	235	266	221	106	114	135
Above Normal (14%)	168	222	270	275	286	271	235	266	221	106	114	135
Below Normal (18%)	168	210	258	278	286	271	235	266	221	106	114	127
Dry (24%)	168	222	270	277	252	251	228	266	221	106	114	135
Critically Dry (16%)	126	122	142	231	206	188	155	231	150	145	131	124
Full Simulation Period Average	162	205	249	301	301	280	220	261	209	112	117	132
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**-32**	**22**	**70**	**85**	**-80**	**69**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Above Normal (14%)	**-32**	**22**	**70**	**82**	**-79**	**71**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Below Normal (18%)	**-32**	**20**	**66**	**84**	**-53**	**71**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Dry (24%)	**-32**	**22**	**70**	**83**	**20**	**59**	**32**	**66**	**-97**	**-44**	**-36**	**-15**
Critically Dry (16%)	**9**	**22**	-1	**54**	**37**	**22**	2	**81**	**-75**	0	**-10**	**-13**
Full Simulation Period Average	**-25**	**22**	**59**	**79**	**-32**	**60**	**29**	**69**	**-94**	**-37**	**-32**	**-14**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-221. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	200	200	200	305	494	300	200	200	318	150	150	150
Above Normal (14%)	200	200	200	193	365	200	200	200	318	150	150	150
Below Normal (18%)	200	190	192	194	339	200	200	200	318	150	150	142
Dry (24%)	200	200	200	194	232	192	196	200	318	150	150	150
Critically Dry (16%)	117	100	143	177	169	166	153	150	225	145	141	137
Full Simulation Period Average	187	183	190	222	333	221	192	192	303	149	149	146
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	168	222	270	390	414	369	235	266	221	106	114	135
Above Normal (14%)	168	222	270	275	286	271	235	266	221	106	114	135
Below Normal (18%)	168	210	258	278	286	271	235	266	221	106	114	127
Dry (24%)	168	222	270	277	252	251	228	266	221	106	114	135
Critically Dry (16%)	127	122	142	231	206	188	155	231	150	145	131	124
Full Simulation Period Average	162	205	249	301	301	280	220	261	209	112	117	132
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**-32**	**22**	**70**	**85**	**-80**	**69**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Above Normal (14%)	**-32**	**22**	**70**	**82**	**-79**	**71**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Below Normal (18%)	**-32**	**20**	**66**	**84**	**-53**	**71**	**35**	**66**	**-97**	**-44**	**-36**	**-15**
Dry (24%)	**-32**	**22**	**70**	**83**	**20**	**59**	**32**	**66**	**-97**	**-44**	**-36**	**-15**
Critically Dry (16%)	**10**	**22**	-1	**54**	**37**	**22**	2	**81**	**-75**	0	**-10**	**-13**
Full Simulation Period Average	**-25**	**22**	**59**	**79**	**-32**	**60**	**29**	**69**	**-94**	**-37**	**-32**	**-14**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

O.5.5 Lower American River

O.5.5.1 Folsom Reservoir Storage

CalSim 3 modeling suggests that monthly average volume of Folsom Reservoir storage under the four phases of Alternative 2 compared to the No Action Alternative are expected to be similar to the projections of the No Action Alternative (Table O-222 through Table O-225). During the implementation of Alternative 2 With TUCP Without VA, simulations show there may be an increase in volume March through December of critically dry type years. Under all other phases of Alternative 2, simulations project decreases in volume April through October of critically dry water types and in some phases August and September of dry water year types; all other water year types have the similar projections as the No Action Alternative (less than 5% difference).

O.5.5.2 Lower American River below Nimbus Dam

CalSim 3 modeling suggests that monthly average flow below Nimbus Dam under the four phases of Alternative 2 compared to the No Action Alternative are not expected to be similar (Table O-226 through Table O-229). During implementation of Alternative 2 With TUCP Without VA, simulations show there may be an increase in flows in December and July (up to 31%) while decreases are expected August through November (up to 9%) and Jan through April (up to 13%) of critically dry type years ; other water year types would be similar or the same as the No Action Alternative the majority of the year (less than 5% difference). Under all other phases of Alternative 2, simulations show there may be an increase in flows in March, April, and June while decreases are expected July through February and May of critically dry type years.

O.5.5.3 Lower American River at H Street

CalSim 3 modeling suggests that monthly average flow in the lower American River at H street under the four phases of Alternative 2 compared to the No Action Alternative are expected to be generally the same or similar projections of the No Action Alternative, except under Alternative 2 With TUCP With Systemwide VAs when there is an increase for averaged April projections (Table O-230 through Table O-233). During implementation of Alternative 2 With TUCP Without VA, simulations show there may be an increase in flows in December and July while decreases are expected in June, August through November, and February through April of critically dry type years; all other year types would be similar or the same as the No Action Alternative most months out of the year. Under all other phases of Alternative 2, simulations show there may be an increase in flows in March, April, and June while decreases are expected July through February and May of critically dry type years; all other year types would be similar or the same as the No Action Alternative most months out of the year.

Table O-222. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	621	533	532	567	567	750	890	947	923	781	693	654
Above Normal (14%)	484	447	502	557	565	745	879	932	858	633	570	518
Below Normal (18%)	454	433	485	540	560	711	836	846	790	576	502	476
Dry (24%)	436	439	470	472	518	633	716	725	657	532	471	447
Critically Dry (16%)	341	318	430	430	452	503	529	524	500	440	376	362
Full Simulation Period Average	484	447	489	516	535	675	779	806	758	609	537	507
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	622	533	530	567	567	750	890	947	922	786	698	657
Above Normal (14%)	474	438	494	559	567	745	880	928	847	640	567	510
Below Normal (18%)	463	445	492	550	561	714	843	841	789	590	504	479
Dry (24%)	423	432	473	483	527	647	728	718	654	515	447	427
Critically Dry (16%)	387	368	462	440	472	532	562	558	541	474	420	411
Full Simulation Period Average	488	454	494	522	541	683	789	808	762	615	540	510
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	1	0	-2	0	0	0	0	0	-1	5	4	3
Above Normal (14%)	-10	-9	-7	2	2	1	1	-4	-12	7	-3	-8
Below Normal (18%)	9	11	7	10	0	3	6	-4	-1	14	2	3
Dry (24%)	-13	-6	3	11	10	14	11	-7	-2	-17	**-24**	-20
Critically Dry (16%)	**46**	**50**	**32**	10	20	**29**	**33**	**34**	**41**	**34**	**44**	**49**
Full Simulation Period Average	4	7	5	6	6	9	9	2	4	6	2	3

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-223. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	621	533	532	567	567	750	890	947	923	781	693	654
Above Normal (14%)	484	447	502	557	565	745	879	932	858	633	570	518
Below Normal (18%)	454	433	485	540	560	711	836	846	790	576	502	476
Dry (24%)	436	439	470	472	518	633	716	725	657	532	471	447
Critically Dry (16%)	341	318	430	430	452	503	529	524	500	440	376	362
Full Simulation Period Average	484	447	489	516	535	675	779	806	758	609	537	507
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	622	533	530	567	567	750	890	947	922	786	698	657
Above Normal (14%)	475	438	494	559	567	745	880	928	847	640	569	512
Below Normal (18%)	464	445	493	545	558	712	843	842	789	588	504	478
Dry (24%)	423	431	472	482	527	647	726	716	653	515	446	427
Critically Dry (16%)	317	311	428	427	461	498	466	481	446	397	351	343
Full Simulation Period Average	478	445	489	519	539	677	773	795	747	602	529	499
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	1	0	-2	0	0	0	0	0	-1	5	4	3
Above Normal (14%)	-10	-9	-7	2	2	1	1	-4	-11	7	0	-6
Below Normal (18%)	10	11	8	5	-2	1	6	-4	-1	11	2	2
Dry (24%)	-13	-8	1	10	10	13	10	-9	-4	-18	**-24**	-20
Critically Dry (16%)	**-24**	-7	-2	-3	9	-4	**-62**	**-43**	**-54**	**-43**	**-25**	**-19**
Full Simulation Period Average	-6	-2	0	3	4	3	-6	-10	-12	-7	-8	-8

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-224. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	621	533	532	567	567	750	890	947	923	781	693	654
Above Normal (14%)	484	447	502	557	565	745	879	932	858	633	570	518
Below Normal (18%)	454	433	485	540	560	711	836	846	790	576	502	476
Dry (24%)	436	439	470	472	518	633	716	725	657	532	471	447
Critically Dry (16%)	341	318	430	430	452	503	529	524	500	440	376	362
Full Simulation Period Average	484	447	489	516	535	675	779	806	758	609	537	507
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	621	530	529	567	567	750	890	946	922	783	695	655
Above Normal (14%)	473	436	493	559	567	745	880	928	848	632	564	507
Below Normal (18%)	461	436	485	543	560	714	842	846	790	590	501	474
Dry (24%)	416	428	464	478	526	645	726	719	653	513	441	420
Critically Dry (16%)	314	299	411	415	448	486	464	477	444	393	342	338
Full Simulation Period Average	475	440	482	516	537	675	772	796	747	600	524	495
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	-3	-3	0	0	0	0	0	-1	2	1	1
Above Normal (14%)	-12	-11	-9	2	2	0	1	-4	-10	-1	-6	-11
Below Normal (18%)	7	2	1	3	-1	3	6	0	0	14	-1	-2
Dry (24%)	-20	-11	-6	6	9	12	9	-6	-4	-19	**-30**	**-27**
Critically Dry (16%)	**-27**	**-19**	-19	-15	-4	-17	**-65**	**-46**	**-56**	**-47**	**-34**	**-24**
Full Simulation Period Average	-9	-8	-6	0	2	1	-7	-9	-11	-9	-13	-12

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-225. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	621	533	532	567	567	750	890	947	923	781	693	654
Above Normal (14%)	484	447	502	557	565	745	879	932	858	633	570	518
Below Normal (18%)	454	433	485	540	560	711	836	846	790	576	502	476
Dry (24%)	436	439	470	472	518	633	716	725	657	532	471	447
Critically Dry (16%)	341	318	430	430	452	503	529	524	500	440	376	362
Full Simulation Period Average	484	447	489	516	535	675	779	806	758	609	537	507
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	620	530	529	567	567	749	890	946	923	781	694	654
Above Normal (14%)	475	438	494	559	567	745	880	925	847	626	561	510
Below Normal (18%)	455	435	484	540	559	713	842	850	794	578	501	473
Dry (24%)	441	439	473	484	528	647	730	731	666	530	461	442
Critically Dry (16%)	320	309	421	427	460	498	464	480	447	394	353	347
Full Simulation Period Average	481	444	486	519	539	677	773	800	751	601	530	501
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	-3	-3	0	0	0	0	0	0	0	1	0
Above Normal (14%)	-9	-8	-8	2	2	0	1	-7	-11	-7	-9	-8
Below Normal (18%)	2	1	-1	0	-1	2	5	4	4	2	-1	-3
Dry (24%)	5	0	2	12	10	14	14	6	10	-2	-9	-5
Critically Dry (16%)	**-21**	-9	-9	-3	8	-5	**-65**	**-44**	**-54**	**-46**	**-23**	-15
Full Simulation Period Average	-3	-3	-3	3	4	3	-6	-6	-7	-8	-7	-5

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-226. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Lower American River below Nimbus Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,870	4,067	4,854	11,628	12,283	7,659	6,803	6,359	3,663	3,631	2,804	2,514
Above Normal (14%)	1,893	2,418	3,339	6,518	7,463	4,965	3,295	3,324	3,311	4,618	2,260	2,283
Below Normal (18%)	1,578	2,012	4,112	2,926	4,355	2,781	2,822	2,947	2,778	4,557	2,449	1,750
Dry (24%)	1,227	2,276	5,167	1,667	3,197	2,077	2,172	2,492	2,598	2,910	1,968	1,529
Critically Dry (16%)	761	1,347	911	1,368	1,759	1,149	970	1,302	1,425	1,613	1,689	1,016
Full Simulation Period Average	1,500	2,612	3,977	5,314	6,317	4,022	3,551	3,583	2,841	3,440	2,285	1,868
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	1,898	4,091	4,877	11,641	12,283	7,659	6,803	6,359	3,683	3,534	2,813	2,539
Above Normal (14%)	1,947	2,387	3,311	6,763	7,468	4,981	3,292	3,393	3,445	4,323	2,412	2,369
Below Normal (18%)	1,479	1,975	4,178	2,828	4,533	2,730	2,770	3,120	2,724	4,315	2,636	1,731
Dry (24%)	1,107	2,170	5,017	1,559	3,225	2,009	2,214	2,794	2,513	3,153	2,077	1,473
Critically Dry (16%)	724	1,267	1,193	1,302	1,590	1,004	892	1,296	1,304	1,705	1,540	925
Full Simulation Period Average	1,471	2,592	3,977	5,343	6,349	3,976	3,541	3,685	2,859	3,391	2,261	1,848
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	27	25	23	13	0	0	0	0	20	-97	8	25
Above Normal (14%)	54	-32	-28	244	5	16	-3	69	134	**-295**	**153**	86
Below Normal (18%)	**-99**	-37	66	-98	178	-51	-52	**174**	-55	**-242**	**186**	-20
Dry (24%)	**-120**	-106	-150	**-108**	27	-68	42	**302**	-84	**244**	**109**	-57
Critically Dry (16%)	-37	**-80**	**283**	-66	**-169**	**-145**	**-78**	-6	**-121**	**92**	**-149**	**-91**
Full Simulation Period Average	-30	-20	0	29	32	-47	-10	103	18	-49	-24	-20

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-227. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Lower American River below Nimbus Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,870	4,067	4,854	11,628	12,283	7,659	6,803	6,359	3,663	3,631	2,804	2,514
Above Normal (14%)	1,893	2,418	3,339	6,518	7,463	4,965	3,295	3,324	3,311	4,618	2,260	2,283
Below Normal (18%)	1,578	2,012	4,112	2,926	4,355	2,781	2,822	2,947	2,778	4,557	2,449	1,750
Dry (24%)	1,227	2,276	5,167	1,667	3,197	2,077	2,172	2,492	2,598	2,910	1,968	1,529
Critically Dry (16%)	761	1,347	911	1,368	1,759	1,149	970	1,302	1,425	1,613	1,689	1,016
Full Simulation Period Average	1,500	2,612	3,977	5,314	6,317	4,022	3,551	3,583	2,841	3,440	2,285	1,868
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	1,898	4,090	4,877	11,641	12,283	7,659	6,803	6,359	3,684	3,532	2,815	2,539
Above Normal (14%)	1,955	2,406	3,312	6,663	7,468	4,981	3,293	3,393	3,439	4,329	2,373	2,384
Below Normal (18%)	1,434	1,994	4,168	2,696	4,478	2,730	2,736	3,113	2,726	4,357	2,601	1,754
Dry (24%)	1,107	2,191	5,017	1,559	3,209	2,013	2,233	2,792	2,511	3,138	2,077	1,473
Critically Dry (16%)	748	1,062	814	1,320	1,553	1,357	1,935	988	1,613	1,438	1,401	921
Full Simulation Period Average	1,464	2,570	3,997	5,298	6,329	3,976	3,539	3,695	2,816	3,401	2,344	1,855
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	28	23	23	13	0	0	0	0	21	-99	11	25
Above Normal (14%)	62	-13	-27	145	5	16	-3	69	128	**-289**	**114**	101
Below Normal (18%)	**-144**	-17	56	**-230**	123	-51	-86	**166**	-52	-200	**152**	4
Dry (24%)	**-121**	-85	-150	**-108**	12	-64	61	**301**	-86	**229**	**109**	-57
Critically Dry (16%)	-13	**-286**	**-97**	-48	**-206**	**208**	**966**	**-314**	**187**	**-175**	**-288**	**-94**
Full Simulation Period Average	-36	-42	21	-16	12	-46	-12	113	-25	-39	59	-13

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-228. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for lower American River below Nimbus Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,870	4,067	4,854	11,628	12,283	7,659	6,803	6,359	3,663	3,631	2,804	2,514
Above Normal (14%)	1,893	2,418	3,339	6,518	7,463	4,965	3,295	3,324	3,311	4,618	2,260	2,283
Below Normal (18%)	1,578	2,012	4,112	2,926	4,355	2,781	2,822	2,947	2,778	4,557	2,449	1,750
Dry (24%)	1,227	2,276	5,167	1,667	3,197	2,077	2,172	2,492	2,598	2,910	1,968	1,529
Critically Dry (16%)	761	1,347	911	1,368	1,759	1,149	970	1,302	1,425	1,613	1,689	1,016
Full Simulation Period Average	1,500	2,612	3,977	5,314	6,317	4,022	3,551	3,583	2,841	3,440	2,285	1,868
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	1,875	4,111	4,855	11,631	12,287	7,654	6,796	6,347	3,641	3,543	2,783	2,503
Above Normal (14%)	1,910	2,397	3,303	6,553	7,481	4,964	3,260	3,337	3,384	4,439	2,298	2,340
Below Normal (18%)	1,405	2,070	4,135	2,641	4,405	2,734	2,747	2,999	2,748	4,281	2,652	1,740
Dry (24%)	1,106	2,108	5,038	1,558	3,192	2,044	2,187	2,681	2,545	3,123	2,117	1,483
Critically Dry (16%)	686	1,130	788	1,267	1,567	1,345	1,760	993	1,672	1,497	1,494	928
Full Simulation Period Average	1,433	2,559	3,926	5,226	6,297	4,036	3,660	3,587	2,866	3,373	2,326	1,846
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	4	44	1	3	3	-5	-8	-11	-22	-89	-21	-11
Above Normal (14%)	17	-21	-35	35	18	0	-35	13	73	-179	39	58
Below Normal (18%)	**-173**	58	23	**-285**	49	-46	-74	52	-30	**-275**	**203**	-10
Dry (24%)	**-121**	**-168**	-130	**-109**	-6	-33	15	**189**	-52	**213**	**149**	-46
Critically Dry (16%)	**-75**	**-217**	**-122**	**-101**	**-192**	**196**	**790**	**-309**	**246**	**-116**	**-195**	**-87**
Full Simulation Period Average	-67	-53	-50	-88	-20	14	110	4	25	-67	41	-22

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-229. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for lower American River below Nimbus Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	1,870	4,067	4,854	11,628	12,283	7,659	6,803	6,359	3,663	3,631	2,804	2,514
Above Normal (14%)	1,893	2,418	3,339	6,518	7,463	4,965	3,295	3,324	3,311	4,618	2,260	2,283
Below Normal (18%)	1,578	2,012	4,112	2,926	4,355	2,781	2,822	2,947	2,778	4,557	2,449	1,750
Dry (24%)	1,227	2,276	5,167	1,667	3,197	2,077	2,172	2,492	2,598	2,910	1,968	1,529
Critically Dry (16%)	761	1,347	911	1,368	1,759	1,149	970	1,302	1,425	1,613	1,689	1,016
Full Simulation Period Average	1,500	2,612	3,977	5,314	6,317	4,022	3,551	3,583	2,841	3,440	2,285	1,868
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	1,888	4,104	4,839	11,590	12,293	7,675	6,809	6,333	3,651	3,534	2,773	2,520
Above Normal (14%)	1,923	2,397	3,325	6,842	7,505	5,029	3,325	3,366	3,406	4,308	2,257	2,229
Below Normal (18%)	1,509	2,023	4,128	2,672	4,367	2,826	2,825	2,962	2,793	4,327	2,451	1,766
Dry (24%)	1,096	2,309	5,057	1,565	3,282	2,148	2,275	2,745	2,547	2,956	2,077	1,468
Critically Dry (16%)	729	1,076	803	1,127	1,579	1,425	2,064	1,099	1,660	1,502	1,345	972
Full Simulation Period Average	1,461	2,588	3,931	5,240	6,319	4,105	3,757	3,613	2,879	3,321	2,247	1,843
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	18	38	-15	-38	10	16	6	-25	-12	-97	-31	6
Above Normal (14%)	31	-22	-14	323	42	64	30	42	95	**-310**	-3	-54
Below Normal (18%)	-69	11	16	**-254**	12	45	4	16	15	**-229**	2	15
Dry (24%)	**-131**	33	-110	**-102**	85	71	103	**253**	-50	46	**109**	-62
Critically Dry (16%)	-32	**-272**	**-108**	**-241**	**-180**	**276**	**1,094**	**-204**	**235**	**-111**	**-343**	-44
Full Simulation Period Average	-39	-24	-46	-74	2	83	**206**	30	38	-119	-38	-25

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-230. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,769	4,000	4,824	11,646	12,307	7,643	6,758	6,245	3,516	3,454	2,635	2,367
Above Normal (14%)	1,783	2,340	3,332	6,539	7,493	4,921	3,216	3,200	3,141	4,416	2,082	2,131
Below Normal (18%)	1,467	1,936	4,092	2,902	4,314	2,732	2,736	2,811	2,598	4,344	2,260	1,613
Dry (24%)	1,131	2,200	5,124	1,625	3,176	2,012	2,077	2,351	2,416	2,705	1,777	1,388
Critically Dry (16%)	647	1,251	905	1,303	1,712	1,075	862	1,165	1,244	1,416	1,495	867
Full Simulation Period Average	1,395	2,535	3,953	5,297	6,307	3,976	3,471	3,453	2,671	3,243	2,102	1,723
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	1,795	4,024	4,848	11,659	12,307	7,643	6,758	6,245	3,536	3,357	2,643	2,390
Above Normal (14%)	1,835	2,308	3,304	6,782	7,498	4,937	3,213	3,268	3,274	4,122	2,235	2,214
Below Normal (18%)	1,371	1,900	4,159	2,805	4,491	2,682	2,686	2,983	2,543	4,103	2,444	1,594
Dry (24%)	1,012	2,095	4,974	1,519	3,203	1,945	2,118	2,650	2,333	2,945	1,886	1,332
Critically Dry (16%)	604	1,166	1,184	1,240	1,544	931	785	1,159	1,122	1,506	1,346	778
Full Simulation Period Average	1,358	2,493	3,973	5,282	6,320	3,930	3,460	3,565	2,645	3,203	2,161	1,710
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	26	25	23	13	0	0	0	0	20	-97	8	23
Above Normal (14%)	52	-31	-28	243	5	16	-3	68	133	**-293**	**153**	83
Below Normal (18%)	**-96**	-36	66	-97	177	-50	-51	**173**	-56	**-240**	**184**	-19
Dry (24%)	**-119**	-105	-150	**-107**	27	-68	42	**298**	-84	**240**	**108**	-56
Critically Dry (16%)	**-43**	**-84**	**280**	-63	**-168**	**-144**	**-78**	-6	**-122**	**90**	**-149**	**-89**
Full Simulation Period Average	-37	-42	20	-15	12	-46	-12	111	-25	-39	59	-13

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-231. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,769	4,000	4,824	11,646	12,307	7,643	6,758	6,245	3,516	3,454	2,635	2,367
Above Normal (14%)	1,783	2,340	3,332	6,539	7,493	4,921	3,216	3,200	3,141	4,416	2,082	2,131
Below Normal (18%)	1,467	1,936	4,092	2,902	4,314	2,732	2,736	2,811	2,598	4,344	2,260	1,613
Dry (24%)	1,131	2,200	5,124	1,625	3,176	2,012	2,077	2,351	2,416	2,705	1,777	1,388
Critically Dry (16%)	647	1,251	905	1,303	1,712	1,075	862	1,165	1,244	1,416	1,495	867
Full Simulation Period Average	1,395	2,535	3,953	5,297	6,307	3,976	3,471	3,453	2,671	3,243	2,102	1,723
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	1,795	4,023	4,847	11,659	12,306	7,642	6,758	6,245	3,537	3,355	2,645	2,390
Above Normal (14%)	1,843	2,327	3,306	6,683	7,498	4,937	3,213	3,268	3,268	4,128	2,196	2,229
Below Normal (18%)	1,325	1,919	4,148	2,673	4,435	2,681	2,651	2,975	2,544	4,146	2,409	1,615
Dry (24%)	1,012	2,116	4,974	1,518	3,188	1,949	2,137	2,648	2,330	2,930	1,886	1,332
Critically Dry (16%)	633	969	807	1,258	1,507	1,281	1,821	855	1,429	1,247	1,223	780
Full Simulation Period Average	1,355	2,474	3,914	5,247	6,300	3,986	3,624	3,514	2,694	3,166	2,130	1,716
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	26	23	23	13	0	0	0	0	21	-99	10	24
Above Normal (14%)	60	-12	-26	144	5	16	-3	68	127	**-288**	**114**	98
Below Normal (18%)	**-142**	-17	56	**-229**	121	-51	-86	**164**	-54	-198	**149**	2
Dry (24%)	**-119**	-84	-150	**-107**	12	-63	60	**297**	-86	**225**	**109**	-56
Critically Dry (16%)	-13	**-282**	**-98**	-45	**-205**	**206**	**959**	**-310**	**186**	**-169**	**-272**	**-87**
Full Simulation Period Average	-40	-61	-38	-50	-7	11	152	61	23	-77	28	-7

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-232. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,769	4,000	4,824	11,646	12,307	7,643	6,758	6,245	3,516	3,454	2,635	2,367
Above Normal (14%)	1,783	2,340	3,332	6,539	7,493	4,921	3,216	3,200	3,141	4,416	2,082	2,131
Below Normal (18%)	1,467	1,936	4,092	2,902	4,314	2,732	2,736	2,811	2,598	4,344	2,260	1,613
Dry (24%)	1,131	2,200	5,124	1,625	3,176	2,012	2,077	2,351	2,416	2,705	1,777	1,388
Critically Dry (16%)	647	1,251	905	1,303	1,712	1,075	862	1,165	1,244	1,416	1,495	867
Full Simulation Period Average	1,395	2,535	3,953	5,297	6,307	3,976	3,471	3,453	2,671	3,243	2,102	1,723
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	1,772	4,044	4,825	11,649	12,310	7,638	6,751	6,233	3,494	3,365	2,614	2,355
Above Normal (14%)	1,799	2,319	3,297	6,574	7,510	4,920	3,181	3,213	3,213	4,237	2,121	2,188
Below Normal (18%)	1,297	1,995	4,115	2,618	4,362	2,686	2,662	2,862	2,567	4,070	2,459	1,603
Dry (24%)	1,012	2,033	4,995	1,517	3,170	1,980	2,092	2,539	2,364	2,916	1,926	1,341
Critically Dry (16%)	574	1,037	782	1,205	1,521	1,269	1,648	860	1,488	1,305	1,315	781
Full Simulation Period Average	1,328	2,483	3,902	5,210	6,287	3,989	3,580	3,457	2,695	3,177	2,144	1,701
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	3	44	1	3	3	-5	-8	-12	-22	-88	-21	-11
Above Normal (14%)	16	-21	-35	35	18	-1	-35	12	72	-178	39	58
Below Normal (18%)	**-171**	59	23	**-284**	48	-46	-74	51	-32	**-274**	**199**	-10
Dry (24%)	**-119**	**-167**	-129	**-108**	-6	-32	15	**187**	-52	**211**	**149**	-47
Critically Dry (16%)	**-73**	**-213**	**-123**	**-98**	**-191**	**194**	**786**	**-306**	**244**	**-111**	**-180**	**-86**
Full Simulation Period Average	-67	-52	-50	-87	-20	13	109	4	25	-66	42	-22

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-233. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	1,769	4,000	4,824	11,646	12,307	7,643	6,758	6,245	3,516	3,454	2,635	2,367
Above Normal (14%)	1,783	2,340	3,332	6,539	7,493	4,921	3,216	3,200	3,141	4,416	2,082	2,131
Below Normal (18%)	1,467	1,936	4,092	2,902	4,314	2,732	2,736	2,811	2,598	4,344	2,260	1,613
Dry (24%)	1,131	2,200	5,124	1,625	3,176	2,012	2,077	2,351	2,416	2,705	1,777	1,388
Critically Dry (16%)	647	1,251	905	1,303	1,712	1,075	862	1,165	1,244	1,416	1,495	867
Full Simulation Period Average	1,395	2,535	3,953	5,297	6,307	3,976	3,471	3,453	2,671	3,243	2,102	1,723
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	1,786	4,037	4,809	11,608	12,316	7,658	6,764	6,220	3,504	3,357	2,603	2,372
Above Normal (14%)	1,814	2,318	3,318	6,860	7,535	4,985	3,246	3,242	3,235	4,106	2,079	2,082
Below Normal (18%)	1,400	1,948	4,108	2,649	4,325	2,785	2,750	2,838	2,610	4,115	2,260	1,628
Dry (24%)	1,002	2,232	5,014	1,525	3,260	2,126	2,231	2,667	2,365	2,751	1,885	1,326
Critically Dry (16%)	615	983	796	1,065	1,533	1,398	2,003	1,024	1,476	1,310	1,168	822
Full Simulation Period Average	1,357	2,512	3,907	5,224	6,309	4,077	3,699	3,510	2,708	3,125	2,066	1,699
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	17	38	-15	-38	10	16	5	-26	-13	-97	-32	6
Above Normal (14%)	31	-21	-14	321	42	64	30	42	93	**-309**	-3	-48
Below Normal (18%)	-67	12	16	**-253**	11	53	14	27	12	**-229**	0	15
Dry (24%)	**-129**	32	-110	**-101**	84	**114**	**154**	**315**	-51	46	**107**	-62
Critically Dry (16%)	-32	**-268**	**-108**	**-238**	**-179**	**323**	**1,141**	**-142**	**232**	**-106**	**-327**	**-45**
Full Simulation Period Average	-38	-23	-46	-73	2	102	**228**	57	37	-118	-36	-25

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

O.5.6 Stanislaus River

O.5.6.1 Stanislaus River below Goodwin Dam

CalSim 3 modeling suggests monthly average flows (throughout the full simulation period) below Goodwin Dam under all phases of Alternative 2 compared to the No Action Alternative are higher December, February, July, and August and lower in April compared to the No Action Alternative (Table O-234 through Table O-237). The greatest increases under the four phases of Alternative 2 are expected in June through August of critically dry water year types. The greatest decreases under the four phases of Alternative 2 are expected in January of an above normal water year type.

O.5.6.2 Stanislaus River at Mouth

CalSim 3 modeling suggests monthly average flows (throughout the full simulation period) at the mouth of the Stanislaus under the four phases of Alternative 2 compared to the No Action Alternative are higher in August and September, while all other months would be the same or similar to the No Action Alternative (Table O-238 through Table O-241). All phases of Alternative 2 compared to No Action Alternative have the largest projected flow increases in June through September of critically dry water year types. All phases of Alternative 2 compared to No Action Alternative have the largest projected flow decreases in January of above normal water year types and May of below normal water year types.

Table O-234. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	875	578	752	2,005	2,111	1,887	1,680	1,984	747	288	741	870
Above Normal (14%)	742	200	352	782	1,297	889	1,177	1,134	456	273	287	260
Below Normal (18%)	685	200	462	417	641	382	846	868	335	267	284	280
Dry (24%)	617	200	490	241	230	200	636	563	269	265	283	249
Critically Dry (16%)	591	200	200	217	219	200	529	453	262	268	283	249
All	716	306	494	838	978	802	1,025	1,078	440	273	412	430
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	870	580	787	2,001	2,156	1,837	1,627	2,023	626	280	780	869
Above Normal (14%)	729	200	352	577	1,311	892	1,112	1,063	415	270	285	257
Below Normal (18%)	649	200	472	440	726	347	672	715	317	267	312	327
Dry (24%)	612	200	581	224	335	200	531	544	269	265	283	249
Critically Dry (16%)	591	200	200	200	313	200	527	453	418	419	435	249
All	705	306	527	806	1,048	782	944	1,047	422	295	452	438
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-4	2	35	-4	45	-50	-53	39	**-121**	-7	**39**	-1
Above Normal (14%)	-13	0	0	**-205**	14	3	**-65**	**-72**	**-41**	-2	-1	-4
Below Normal (18%)	**-36**	0	10	**24**	**85**	**-35**	**-174**	**-153**	**-18**	0	**28**	**47**
Dry (24%)	-5	0	**90**	**-17**	**104**	0	**-105**	-19	0	0	0	0
Critically Dry (16%)	0	0	0	**-17**	**94**	0	-2	0	**156**	**151**	**152**	0
All	-11	1	**33**	-32	**70**	-20	**-81**	-31	-18	**22**	**40**	8

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-235. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	875	578	752	2,005	2,111	1,887	1,680	1,984	747	288	741	870
Above Normal (14%)	742	200	352	782	1,297	889	1,177	1,134	456	273	287	260
Below Normal (18%)	685	200	462	417	641	382	846	868	335	267	284	280
Dry (24%)	617	200	490	241	230	200	636	563	269	265	283	249
Critically Dry (16%)	591	200	200	217	219	200	529	453	262	268	283	249
All	716	306	494	838	978	802	1,025	1,078	440	273	412	430
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	870	579	787	2,001	2,149	1,795	1,627	2,019	626	280	780	868
Above Normal (14%)	729	200	352	526	1,302	886	1,112	1,063	415	270	285	257
Below Normal (18%)	649	200	472	440	726	347	672	715	317	267	312	327
Dry (24%)	612	200	580	224	335	200	531	544	269	265	283	249
Critically Dry (16%)	591	200	200	200	313	200	527	453	496	497	511	249
All	705	306	527	799	1,045	769	944	1,046	434	307	464	438
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-4	1	35	-4	37	-92	-53	35	**-121**	-7	**39**	-2
Above Normal (14%)	-13	0	0	**-256**	6	-3	**-65**	**-72**	**-41**	-2	-1	-4
Below Normal (18%)	**-36**	0	10	**23**	**85**	**-35**	**-174**	**-153**	**-18**	0	**28**	**47**
Dry (24%)	-5	0	**90**	**-17**	**104**	0	**-105**	-19	0	0	0	0
Critically Dry (16%)	0	0	0	**-17**	**94**	0	-2	0	**233**	**229**	**228**	0
All	-11	0	**33**	-39	**67**	-33	**-81**	-32	-6	**34**	**52**	8

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-236. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	875	578	752	2,005	2,111	1,887	1,680	1,984	747	288	741	870
Above Normal (14%)	742	200	352	782	1,297	889	1,177	1,134	456	273	287	260
Below Normal (18%)	685	200	462	417	641	382	846	868	335	267	284	280
Dry (24%)	617	200	490	241	230	200	636	563	269	265	283	249
Critically Dry (16%)	591	200	200	217	219	200	529	453	262	268	283	249
All	716	306	494	838	978	802	1,025	1,078	440	273	412	430
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	869	579	788	2,001	2,149	1,795	1,627	2,019	626	280	780	868
Above Normal (14%)	729	200	352	526	1,303	886	1,112	1,063	415	270	285	257
Below Normal (18%)	649	202	472	442	726	347	672	715	317	267	312	327
Dry (24%)	612	200	580	224	336	200	531	544	269	265	283	249
Critically Dry (16%)	591	200	200	200	313	200	527	453	496	497	511	249
All	705	306	528	799	1,045	769	944	1,046	434	307	464	438
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-6	1	36	-4	37	-92	-53	35	**-121**	-7	**39**	-2
Above Normal (14%)	-13	0	0	**-256**	6	-3	**-65**	**-72**	**-41**	-2	-1	-4
Below Normal (18%)	**-36**	2	10	**25**	**85**	**-35**	**-174**	**-153**	**-18**	0	**28**	**47**
Dry (24%)	-5	0	**90**	**-17**	**105**	0	**-105**	-19	0	0	0	0
Critically Dry (16%)	0	0	0	**-17**	**94**	0	-2	0	**233**	**229**	**228**	0
All	-11	1	**33**	-39	**67**	-33	**-81**	-32	-6	**34**	**52**	8

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-237. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	875	578	752	2,005	2,111	1,887	1,680	1,984	747	288	741	870
Above Normal (14%)	742	200	352	782	1,297	889	1,177	1,134	456	273	287	260
Below Normal (18%)	685	200	462	417	641	382	846	868	335	267	284	280
Dry (24%)	617	200	490	241	230	200	636	563	269	265	283	249
Critically Dry (16%)	591	200	200	217	219	200	529	453	262	268	283	249
All	716	306	494	838	978	802	1,025	1,078	440	273	412	430
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	870	580	788	2,001	2,156	1,836	1,627	2,023	626	280	780	869
Above Normal (14%)	729	200	352	574	1,308	892	1,112	1,063	415	270	285	257
Below Normal (18%)	649	202	472	442	726	347	672	715	317	267	312	327
Dry (24%)	612	200	580	224	336	200	531	544	269	265	283	249
Critically Dry (16%)	591	200	200	200	313	200	527	453	418	419	435	249
All	705	307	528	806	1,048	781	944	1,047	422	295	452	438
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-5	2	36	-4	45	-51	-53	39	**-121**	-7	**39**	-1
Above Normal (14%)	-13	0	0	**-208**	11	3	**-65**	**-72**	**-41**	-2	-1	-4
Below Normal (18%)	**-36**	2	10	**25**	**85**	**-35**	**-174**	**-153**	**-18**	0	**28**	**47**
Dry (24%)	-5	0	**90**	**-17**	**105**	0	**-105**	-19	0	0	0	0
Critically Dry (16%)	0	0	0	**-17**	**94**	0	-2	0	**156**	**151**	**152**	0
All	-11	1	**33**	-32	**70**	-20	**-81**	-31	-18	**22**	**40**	8

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-238. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	844	777	777	1,818	2,241	2,015	1,903	2,079	1,047	549	653	771
Above Normal (14%)	559	413	411	778	1,290	1,052	1,205	1,243	643	377	313	274
Below Normal (18%)	530	396	468	450	676	519	870	984	513	312	293	291
Dry (24%)	474	354	470	330	395	276	601	707	362	235	257	258
Critically Dry (16%)	404	303	245	290	343	210	478	550	252	135	185	191
All	590	482	513	825	1,079	905	1,079	1,191	603	340	370	399
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	843	778	793	1,832	2,252	2,006	1,880	2,090	995	520	662	777
Above Normal (14%)	555	411	410	662	1,233	1,054	1,191	1,183	610	362	313	278
Below Normal (18%)	533	393	474	480	725	525	798	881	472	300	311	342
Dry (24%)	473	354	522	322	435	299	575	674	351	231	257	260
Critically Dry (16%)	429	313	249	283	379	229	487	554	315	245	309	246
All	593	482	531	814	1,099	912	1,053	1,160	583	345	396	420
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	1	16	14	11	-9	-23	12	-52	**-29**	10	6
Above Normal (14%)	-4	-3	-1	**-117**	-57	2	-14	-60	**-34**	-15	0	5
Below Normal (18%)	3	-4	5	**30**	**50**	6	**-72**	**-103**	**-41**	-12	**19**	**50**
Dry (24%)	-1	-1	**51**	-7	**40**	**23**	-26	-33	-11	-4	1	2
Critically Dry (16%)	**25**	10	4	-7	**36**	**19**	9	4	**63**	**110**	**124**	**55**
All	3	0	18	-10	19	8	-26	-31	-19	4	**26**	**21**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-239. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	844	777	777	1,818	2,241	2,015	1,903	2,079	1,047	549	653	771
Above Normal (14%)	559	413	411	778	1,290	1,052	1,205	1,243	643	377	313	274
Below Normal (18%)	530	396	468	450	676	519	870	984	513	312	293	291
Dry (24%)	474	354	470	330	395	276	601	707	362	235	257	258
Critically Dry (16%)	404	303	245	290	343	210	478	550	252	135	185	191
All	590	482	513	825	1,079	905	1,079	1,191	603	340	370	399
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	843	777	793	1,832	2,248	1,985	1,868	2,082	993	519	662	776
Above Normal (14%)	555	410	410	639	1,215	1,038	1,187	1,182	609	362	313	278
Below Normal (18%)	532	392	473	480	725	525	797	881	471	300	311	342
Dry (24%)	473	353	521	322	435	299	575	673	351	232	257	260
Critically Dry (16%)	442	317	251	282	379	229	487	554	346	299	371	271
All	595	482	531	811	1,095	904	1,049	1,157	588	353	406	423
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-2	0	16	13	7	-30	-35	3	**-54**	**-29**	9	5
Above Normal (14%)	-5	-3	-2	**-139**	**-75**	-15	-17	-61	**-34**	-15	0	4
Below Normal (18%)	3	-4	5	**29**	**49**	6	**-73**	**-104**	**-42**	-12	**18**	**50**
Dry (24%)	-1	-1	**51**	-7	**40**	**23**	-26	-33	-11	-3	1	3
Critically Dry (16%)	**38**	14	5	-7	**35**	**19**	9	4	**94**	**164**	**186**	**80**
All	5	1	18	-13	16	-1	-30	-34	-15	13	**36**	**25**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-240. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	844	777	777	1,818	2,241	2,015	1,903	2,079	1,047	549	653	771
Above Normal (14%)	559	413	411	778	1,290	1,052	1,205	1,243	643	377	313	274
Below Normal (18%)	530	396	468	450	676	519	870	984	513	312	293	291
Dry (24%)	474	354	470	330	395	276	601	707	362	235	257	258
Critically Dry (16%)	404	303	245	290	343	210	478	550	252	135	185	191
All	590	482	513	825	1,079	905	1,079	1,191	603	340	370	399
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	841	777	793	1,832	2,248	1,985	1,868	2,081	992	519	662	776
Above Normal (14%)	554	410	410	639	1,215	1,037	1,186	1,182	608	362	313	277
Below Normal (18%)	531	392	474	480	726	524	797	881	472	300	310	341
Dry (24%)	471	353	521	322	435	299	575	673	351	230	257	260
Critically Dry (16%)	441	317	251	282	379	228	487	554	347	300	371	272
All	593	482	532	811	1,095	903	1,048	1,157	588	353	406	423
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-4	-1	16	13	7	-30	-35	2	**-55**	**-29**	9	5
Above Normal (14%)	-6	-3	-2	**-139**	**-75**	-15	-18	-61	**-36**	-14	0	4
Below Normal (18%)	1	-4	6	**30**	**50**	6	**-73**	**-104**	**-41**	-12	**17**	**49**
Dry (24%)	-3	-1	**51**	-7	**40**	**22**	-26	-33	-11	-4	0	2
Critically Dry (16%)	**37**	14	5	-7	**35**	**19**	9	4	**95**	**165**	**186**	**81**
All	3	1	18	-13	16	-1	-30	-34	-15	13	**35**	**24**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-241. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	844	777	777	1,818	2,241	2,015	1,903	2,079	1,047	549	653	771
Above Normal (14%)	559	413	411	778	1,290	1,052	1,205	1,243	643	377	313	274
Below Normal (18%)	530	396	468	450	676	519	870	984	513	312	293	291
Dry (24%)	474	354	470	330	395	276	601	707	362	235	257	258
Critically Dry (16%)	404	303	245	290	343	210	478	550	252	135	185	191
All	590	482	513	825	1,079	905	1,079	1,191	603	340	370	399
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	842	778	793	1,831	2,252	2,005	1,880	2,090	994	520	662	776
Above Normal (14%)	554	410	410	660	1,230	1,053	1,189	1,183	609	363	313	278
Below Normal (18%)	531	393	474	480	726	525	797	881	472	300	310	341
Dry (24%)	471	353	521	322	436	299	575	674	352	231	257	260
Critically Dry (16%)	429	313	249	283	379	228	487	554	316	246	309	245
All	592	482	531	814	1,099	912	1,052	1,160	584	345	396	419
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-2	0	17	13	11	-9	-23	11	**-53**	**-29**	9	6
Above Normal (14%)	-5	-3	-1	**-118**	-60	1	-15	-60	**-35**	-14	0	5
Below Normal (18%)	1	-4	6	**30**	**50**	6	**-72**	**-103**	**-41**	-12	**17**	**49**
Dry (24%)	-3	-1	**51**	-7	**41**	**23**	-26	-33	-11	-4	0	2
Critically Dry (16%)	**25**	10	4	-7	**36**	**18**	9	4	**65**	**111**	**125**	**54**
All	2	0	18	-10	19	7	-26	-31	-19	5	**26**	**20**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

O.5.7 San Joaquin River

O.5.7.1 San Joaquin River at Vernalis

CalSim 3 modeling indicates that average flow in the San Joaquin River at Vernalis under the four phases of Alternative 2 compared to No Action Alternative are similar (less than 5% difference) October through May and occasionally increase in critically dry, above normal, and below normal water year types June through September (Table O-242 through Table O-245). The largest increases under the four phases of Alternative 2 compared to the No Action Alternative are expected in July and August of critically dry water year types. There are no anticipated decreases greater than 5% difference under the four phases of Alternative 2 compared to the No Action Alternative. Throughout the full simulation period, average flows are similar (less than 5% difference) under the four phases of Alternative 2 from October through September.

Table O-242. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 2 With TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	2,982	2,957	4,091	9,879	13,068	12,499	12,532	11,481	7,391	3,577	2,375	2,263
Above Normal (14%)	2,222	1,876	2,549	4,210	7,063	6,332	6,587	4,709	3,201	1,899	1,412	1,367
Below Normal (18%)	1,830	1,720	2,722	2,738	4,312	4,104	4,914	3,862	2,439	1,486	1,183	1,215
Dry (24%)	1,542	1,514	2,585	1,992	2,732	2,550	2,992	2,406	1,486	963	925	1,019
Critically Dry (16%)	1,288	1,244	1,499	1,821	2,162	2,038	2,287	1,665	1,129	560	616	738
All	2,061	1,969	2,863	4,618	6,425	6,063	6,399	5,413	3,494	1,856	1,396	1,407
ALTERNATIVE 2 WITH TUCP WITHOUT VA												
Wet (28%)	2,981	2,958	4,108	9,896	13,079	12,489	12,496	11,490	7,336	3,546	2,386	2,272
Above Normal (14%)	2,203	1,861	2,543	4,092	7,004	6,328	6,572	4,654	3,171	1,896	1,421	1,373
Below Normal (18%)	1,826	1,718	2,731	2,768	4,372	4,112	4,837	3,742	2,391	1,473	1,215	1,268
Dry (24%)	1,535	1,503	2,637	1,979	2,771	2,569	2,962	2,363	1,469	951	920	1,018
Critically Dry (16%)	1,299	1,241	1,483	1,803	2,187	2,056	2,295	1,666	1,192	673	742	797
All	2,057	1,963	2,878	4,606	6,445	6,069	6,368	5,376	3,472	1,859	1,425	1,428
ALTERNATIVE 2 WITH TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	0	17	17	11	-10	-35	8	-54	-31	12	8
Above Normal (14%)	-19	-15	-6	-118	-59	-4	-15	-55	-30	-3	9	6
Below Normal (18%)	-4	-1	9	29	60	8	-77	-119	-48	-13	32	53
Dry (24%)	-7	-11	51	-12	39	19	-30	-42	-18	-12	-5	-1
Critically Dry (16%)	10	-3	-17	-18	26	19	8	1	**63**	**113**	**126**	**59**
All	-4	-6	15	-12	19	6	-32	-37	-22	4	29	22

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-243. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 2 Without TUCP Without VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	2,982	2,957	4,091	9,879	13,068	12,499	12,532	11,481	7,391	3,577	2,375	2,263
Above Normal (14%)	2,222	1,876	2,549	4,210	7,063	6,332	6,587	4,709	3,201	1,899	1,412	1,367
Below Normal (18%)	1,830	1,720	2,722	2,738	4,312	4,104	4,914	3,862	2,439	1,486	1,183	1,215
Dry (24%)	1,542	1,514	2,585	1,992	2,732	2,550	2,992	2,406	1,486	963	925	1,019
Critically Dry (16%)	1,288	1,244	1,499	1,821	2,162	2,038	2,287	1,665	1,129	560	616	738
All	2,061	1,969	2,863	4,618	6,425	6,063	6,399	5,413	3,494	1,856	1,396	1,407
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA												
Wet (28%)	2,980	2,957	4,107	9,897	13,077	12,467	12,483	11,480	7,334	3,545	2,386	2,270
Above Normal (14%)	2,217	1,863	2,543	4,070	6,983	6,310	6,568	4,653	3,169	1,893	1,419	1,385
Below Normal (18%)	1,831	1,720	2,731	2,762	4,374	4,112	4,835	3,737	2,385	1,467	1,211	1,266
Dry (24%)	1,525	1,497	2,627	1,984	2,772	2,568	2,961	2,361	1,467	950	918	1,013
Critically Dry (16%)	1,328	1,274	1,514	1,809	2,189	2,056	2,295	1,665	1,233	747	825	828
All	2,062	1,967	2,881	4,604	6,442	6,060	6,363	5,372	3,476	1,869	1,437	1,433
ALTERNATIVE 2 WITHOUT TUCP WITHOUT VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-2	-1	16	18	9	-33	-49	-1	-57	-32	11	7
Above Normal (14%)	-5	-14	-7	-141	-79	-22	-19	-57	-32	-6	7	18
Below Normal (18%)	1	0	9	24	62	8	-79	-124	-54	-19	28	51
Dry (24%)	-18	-18	42	-7	41	19	-31	-44	-19	-13	-7	-6
Critically Dry (16%)	40	30	15	-12	28	19	8	0	**105**	**187**	**208**	**90**
All	1	-2	17	-14	17	-3	-37	-41	-18	13	41	27

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-244. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 2 Without TUCP With Delta VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	2,982	2,957	4,091	9,879	13,068	12,499	12,532	11,481	7,391	3,577	2,375	2,263
Above Normal (14%)	2,222	1,876	2,549	4,210	7,063	6,332	6,587	4,709	3,201	1,899	1,412	1,367
Below Normal (18%)	1,830	1,720	2,722	2,738	4,312	4,104	4,914	3,862	2,439	1,486	1,183	1,215
Dry (24%)	1,542	1,514	2,585	1,992	2,732	2,550	2,992	2,406	1,486	963	925	1,019
Critically Dry (16%)	1,288	1,244	1,499	1,821	2,162	2,038	2,287	1,665	1,129	560	616	738
All	2,061	1,969	2,863	4,618	6,425	6,063	6,399	5,413	3,494	1,856	1,396	1,407
ALTERNATIVE WITHOUT TUCP WITH DELTA VA												
Wet (28%)	2,979	2,958	4,109	9,896	13,076	12,455	12,483	11,482	7,334	3,545	2,384	2,268
Above Normal (14%)	2,224	1,867	2,543	4,070	6,984	6,320	6,585	4,659	3,172	1,895	1,417	1,392
Below Normal (18%)	1,821	1,718	2,731	2,764	4,406	4,173	4,869	3,754	2,386	1,464	1,207	1,260
Dry (24%)	1,530	1,499	2,631	1,985	2,791	2,663	3,024	2,372	1,473	950	916	1,015
Critically Dry (16%)	1,326	1,284	1,524	1,809	2,208	2,134	2,322	1,676	1,240	748	828	824
All	2,062	1,970	2,884	4,604	6,455	6,104	6,391	5,380	3,479	1,869	1,436	1,432
ALTERNATIVE WITHOUT TUCP WITH DELTA VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-2	0	18	17	9	-45	-49	1	-56	-32	10	5
Above Normal (14%)	3	-10	-7	-140	-79	-12	-1	-50	-29	-4	5	25
Below Normal (18%)	-8	-1	10	26	94	69	-45	-108	-53	-22	25	45
Dry (24%)	-12	-16	46	-7	60	113	32	-34	-13	-13	-10	-5
Critically Dry (16%)	38	40	24	-12	47	97	35	11	**112**	**188**	**212**	**86**
All	1	1	20	-14	30	41	-9	-33	-15	13	39	26

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

Table O-245. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 2 Without TUCP With Systemwide VA and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	2,982	2,957	4,091	9,879	13,068	12,499	12,532	11,481	7,391	3,577	2,375	2,263
Above Normal (14%)	2,222	1,876	2,549	4,210	7,063	6,332	6,587	4,709	3,201	1,899	1,412	1,367
Below Normal (18%)	1,830	1,720	2,722	2,738	4,312	4,104	4,914	3,862	2,439	1,486	1,183	1,215
Dry (24%)	1,542	1,514	2,585	1,992	2,732	2,550	2,992	2,406	1,486	963	925	1,019
Critically Dry (16%)	1,288	1,244	1,499	1,821	2,162	2,038	2,287	1,665	1,129	560	616	738
All	2,061	1,969	2,863	4,618	6,425	6,063	6,399	5,413	3,494	1,856	1,396	1,407
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA												
Wet (28%)	2,980	2,957	4,107	9,925	13,089	12,488	12,500	11,489	7,338	3,572	2,386	2,272
Above Normal (14%)	2,218	1,861	2,541	4,091	7,000	6,337	6,590	4,661	3,174	2,016	1,435	1,400
Below Normal (18%)	1,826	1,719	2,733	2,773	4,389	4,174	4,870	3,778	2,389	1,578	1,220	1,269
Dry (24%)	1,535	1,504	2,642	1,986	2,793	2,673	3,024	2,373	1,474	1,004	921	1,024
Critically Dry (16%)	1,315	1,270	1,513	1,814	2,211	2,135	2,322	1,675	1,205	691	757	804
All	2,061	1,968	2,884	4,618	6,459	6,118	6,397	5,387	3,475	1,918	1,431	1,435
ALTERNATIVE 2 WITHOUT TUCP WITH SYSTEMWIDE VA MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-2	-1	16	46	21	-12	-31	7	-53	-5	12	9
Above Normal (14%)	-4	-15	-9	-120	-63	5	3	-48	-27	**117**	23	33
Below Normal (18%)	-4	-1	11	35	77	69	-44	-84	-50	**92**	37	54
Dry (24%)	-8	-11	57	-6	61	124	32	-32	-12	41	-4	5
Critically Dry (16%)	27	27	14	-8	49	97	36	11	**76**	**131**	**141**	**66**
All	0	-1	21	0	33	55	-3	-26	-18	62	35	28

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold magenta font indicates a greater than 5% reduction in flow.

O.5.8 Sacramento River Winter-run Chinook Salmon ESU

O.5.8.1 Sacramento River

Spawning and Egg/Alevin Incubation

Winter-run Chinook salmon adults spawn from April through August with peak spawning between May and July (Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). Fry emergence occurs up to 3 months after eggs are spawned, so effects of flow and water temperature on winter-run eggs and alevins may occur from May through November, but primarily occur during June through October.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under the four phases of Alternative 2, differences in mean spawning WUA are increases in wet, above normal, below normal, and dry water year types, and decreases in critically dry water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between the four phases of Alternative 2 and the No Action Alternative is a 3% increase in dry water years under Alternative 2 Without TUCP Systemwide VA. The largest reduction in estimated spawning habitat is a -0.7% decrease in critically dry water year types under Alternative 2 Without TUCP with Delta VA.

The monthly median values of spawning WUA under the four phases of Alternative 2 are similar to the No Action Alternative in May, June, and August but are slightly higher in July (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are relatively similar in May, June, and August. In July, the median values of spawning WUA are lower across all alternatives when compared to the other months of spawning. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in July than in the other three months (Table O-182 through Table O-185). This results in lower spawning WUA results because the winter-run spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) peak at relatively low flows (approximately 5,000 to 10,000 cfs).

The results of suitable habitat availability analysis using the SIT LCM habitat models indicate that spawning habitat for winter-run Chinook salmon in the upper Sacramento River may not be a limiting factor under both the No Action Alternative and the four phases of Alternative 2 (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The results of the two spawning habitat analyses based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 may have a minor increase (less than 3.1%) and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative, and that spawning habitat may not be a limiting factor for winter-run Chinook salmon in the mainstem upper Sacramento River.

Redd Dewatering Analysis

All phases of Alternative 2 show a general increase in mean redd dewatering potential from wet to dry water year types, but the differences are modest (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). During winter and spring, the principal incubation periods for the other Chinook salmon races and steelhead, redd dewatering is generally higher during wet water years because periodic storms and high runoff, which increase flow fluctuations, tend to be more frequent in such water years. However, winter-run spawning and incubation occur during late spring through early fall, when flows tend to be less variable. The minimum rates of redd dewatering for winter-run during wet years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*) may result from increased stability in project operations related to greater reservoir storage levels. The mean redd dewatering potential for all water year types except critically dry years is lower under the four phases of Alternative 2 than under the No Action Alternative (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The largest reduction for all water year types is 26.2% under Alternative 2 With TUCP Without VA in critically dry water years. Note that this reduction, which is computed as the relative (percent) difference between the means of 13.9% and 10.3%, corresponds to an absolute difference of 3.6%. For the other phases of Alternative 2, redd dewatering in critically dry water years is higher than that under No Action Alternative, including an increase of 11.8% for Alternative 2 Without TUCP Without VA.

Overall, the results indicate that redd dewatering potential under the four phases of Alternative 2 would be lower than under the No Action Alternative.

SIT Winter-run Chinook Salmon Lifecycle Model: Spawner Abundance

- In the CVPIA Winter-run Chinook Salmon SIT Lifecycle Model, mean winter-run Chinook salmon spawner abundance in **Alternative 2 With TUCP Without VA** is similar to the abundance under the No Action Alternative. The largest abundance increase between Alternative 2 With TUCP Without VA and the No Action Alternative abundance was 1.8% during above normal water years, and the largest decrease was 1.6% during critically dry years. The annual abundance change between all water year types was similar between Alternative 2 With TUCP Without VA and the No Action Alternative.

- In the other three phases of Alternative 2 (**Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VA**), annual abundance is slightly lower (0.1%) than the No Action Alternative, and the total abundance change in these three phases of Alternative 2 was slightly lower (from no change to -2.1%) compared to the No Action Alternative. Of these three phases, the greatest increase in annual spawner abundance was 4.8% between Alternative 2 Without TUCP With Systemwide VA and the No Action Alternative during wet water year types. The largest decrease annual in spawner abundance was 4.8% between Alternative 2 Without TUCP With Systemwide VA and the No Action Alternative during critically dry water year types.

Overall, all phases of Alternative 2 and the No Action Alternative had mean annual decreases in spawner abundance, with annual increases during dry and wet years and decreases during critically dry and above normal water year types.

IOS: Egg Survival

- Under **Alternative 2 With TUCP Without VA**, in critically dry water years, mean predicted winter-run Chinook salmon egg survival is 29.87% higher than when compared to the No Action Alternative (Attachment F.5, *Interactive Object-oriented Simulation Model*). Alternative 2 With TUCP Without VA reflects a change of 0.21 mean proportion predicted to survive when compared to the No Action Alternative. The change in mean predicted winter-run Chinook salmon egg survival in all other water year types less than or equal to 0.000. Alternative 2 With TUCP Without VA provides a substantial benefit to predicted survival of winter-run Chinook salmon eggs during critically dry water years when compared to the No Action Alternative.

- Under **Alternative 2 Without TUCP Without VA**, in critically dry water years, mean predicted winter-run Chinook salmon egg survival is 2.23% lower than when compared to the No Action Alternative. Alternative 2 With TUCP Without VA reflects a change of -0.02 mean proportion predicted to survive when compared to the No Action Alternative. The change in mean predicted winter-run Chinook salmon egg survival in all water year types less than or equal to 0.000.

- Under **Alternative 2 Without TUCP Delta VA**, in critically dry water years, mean predicted winter-run Chinook salmon egg survival is 3.63% lower than when compared to the No Action Alternative. Alternative 2 Without TUCP Delta VA reflects a change of -0.025 mean proportion predicted to survive when compared to the No Action Alternative. The change in mean predicted winter-run Chinook salmon egg survival in all other water year types less than or equal to 0.000.

- Under **Alternative 2 Without TUCP Systemwide VA**, in critically dry water years, mean predicted winter-run Chinook salmon egg survival is 4.94% lower than when compared to the No Action Alternative. However, the change in mean predicted winter-run Chinook salmon egg survival in all water year types less than or equal to 0.000.

OBAN: Spawner Abundance and Probability of Quasi-Extinction

Predicted spawner abundance under all four phases of Alternative 2 was greater under the No Action Alternative (46% greater under Alternative 2 With TUCP Without VA to 80% greater under Alternative 2 Without TUCP With Delta VA), and spawner abundance is greater than one (Table O-30).

Probability of quasi-extinction under all four phases of Alternative 2 was less under the No Action Alternative (0.97 under phases of Alternative 2, Table O-30).

IOS: Female Escapement

- Under **Alternative 2 With TUCP Without VA** in all water year types, mean annual predicted female escapement of winter-run Chinook salmon is 6.3-10.84% higher than when compared to the No Action Alternative. The change in mean annual predicted female escapement of in all water year types ranging from 167 to 398 individuals. Alternative 2 With TUCP Without VA provides a slightly positive impact to mean annual predicted female escapement of winter-run Chinook salmon when compared to the No Action Alternative.

- Under **Alternative 2 Without TUCP Without VA** in all water year types, mean annual predicted female escapement of winter-run Chinook salmon is 2.06-5.41% higher than when compared to the No Action Alternative. The change in mean annual predicted female escapement of in all water year types ranging from 43-197 individuals. Alternative 2 Without TUCP Without VA provides a slightly positive impact to mean annual predicted female escapement of winter-run Chinook salmon when compared to the No Action Alternative.

- Under **Alternative 2 Without TUCP Delta VA** in all water year types except critical and wet, mean annual predicted female escapement of winter-run Chinook salmon is 0.12-1.85% higher than when compared to the No Action Alternative. The change in mean annual predicted female escapement of in all water year types ranging from -57-68 individuals.

- Under **Alternative 2 Without TUCP Systemwide VA** in all water year types except above normal, critical and wet, mean annual predicted female Escapement of winter-run Chinook salmon is 1.44-1.79% higher than when compared to the No Action Alternative. The change in mean annual predicted female escapement of in all water year types ranging from -15-53 individuals.

<u>OBAN: Egg to Fry Survival</u>

Egg to fry survival under all four phases of Alternative 2 was greater under the No Action Alternative (0.016 – 0.027 difference, Addendum to Attachment F.6, Table O-30).

<u>Temperature Dependent Mortality</u>

- Under **Alternative 2 Without TUCP Without VA** for the Anderson model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.096, 0.464, and 0.001 (all less than the No Action, up to 67% less in a above normal water year type). Under **Alternative 2 With TUCP Without VA** for the Anderson model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.073, 0.337, and 0.001 (all less than the No Action Alternative, up to 67% less in a wet water year type).

- Under **Alternative 2 Without TUCP Delta VA** for the Anderson model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.099, 0.472, and 0.001 (all less than the No Action Alternative, up to 67% less in a wet water year type). Under **Alternative 2 Without TUCP Systemwide VA** for the Anderson model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.102, 0.503, and 0.002 (all less than the No Action Alternative, up to 33% less in a wet water year type). Expected proportional TDM values for the Anderson model were less under all four phases of Alternative 2 than No Action Alternative for all water year types except wet.

- Under **Alternative 2 Without TUCP Without VA** for the Martin model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.123, 0.561, and 0.007 (all less

than the No Action Alternative, up to 61% less in a wet water year type). Under **Alternative 2 With TUCP Without VA** for the Martin model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.093, 0.427, and 0.008 (all less than the No Action Alternative, up to 50% less in a wet water year type). Under **Alternative 2 Without TUCP Delta VA** for the Martin model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.124, 0.552, and 0.009 (all less than the No Action Alternative, up to 44% less in a wet water year type).

- Under **Alternative 2 Without TUCP Systemwide VA** for the Martin model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.128, 0.6, and 0.008 (all less than the No Action Alternative, up to 50% less in a wet water year type). Expected proportional TDM values for the Martin model were less under all four phases of Alternative 2 than No Action Alternative for all water year types.

Relative to the Anderson model, expected proportional TDM values were higher for the Martin model for all four phases of Alternative 2 across all water year types except a below normal water year type. For the Anderson and Martin models, greater than 80% of modeled water years resulted in expected proportional TDM values less than 0.125. For critically dry water year types, at least 12.5% of modeled water years resulted in expected proportional TDM values less than 0.5 for all phases except Alt2woTUCPAllVA mixed. For above normal and wet water year types only, expected proportional TDM never exceeded 0.125 (Attachment L.2, *Egg-to-fry Survival and Temperature Dependent Mortality*). A decrease in TDM under all four phases of Alternative 2 compared with the No Action Alternative would generally have a beneficial effect on incubating winter-run Chinook salmon eggs, with some potential for negligible and adverse effects in some water year types.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 16 for Keswick Dam and Table 18 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 20 for Keswick Dam and Table 22 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during May through November are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 24 for Keswick Dam and Table 26 for below Clear Creek.

Results for the three analyses are summarized in Table O-31. Table O-31, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 42.1°F to 55°F range for spawning initiation, there were five to nine month-water year type combinations (14.3% to 25.7%) with favorable results, depending on location, and one month-water year type combinations (2.9% of total combinations during the period) with unfavorable results below Keswick Dam (Table O-31). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were two to five combinations (5.7% to 14.3%) with favorable results, depending on location, and two to three combinations (5.7% to 8.6%) with unfavorable results. These results suggest that there would be mostly no effect or positive biologically meaningful water temperature-related effects of Alternative 2 With TUCP Without VA on winter-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River, although there were some negligible positive and negative effects on egg incubation and fry emergence.
- Under **Alternative 2 Without TUCP Without VA** for the 42.1°F to 55°F range for spawning initiation, there were five to 10 month-water year type combinations (14.3% to 28.6%) with favorable results, depending on location, one combination (2.9%) with unfavorable effects below Keswick Dam, and no combinations (0% of total combinations during the period) with unfavorable results below Clear Creek (Table O-31). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four to six combinations (11.4% to 17.1%) with favorable results, depending on location, and one to two combinations (2.9% to 5.7%, respectively) with unfavorable results below Keswick Dam and below Clear Creek, respectively. These results suggest that there would be mostly no effect or positive biologically meaningful temperature-related effects of Alternative 2 Without TUCP Without VA on winter-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River, although there were some negligible negative effects on spawning initiation and egg incubation and fry emergence.
- Under **Alternative 2 Without TUCP Delta VA** for the 42.1°F to 55°F range for spawning initiation, there were five to nine month-water year type combinations (14.3% to 25.7%) with favorable results, depending on location, and no combinations (0% of total combinations during the period) with unfavorable results (Table O-31). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were two to five combinations (5.7% to 14.3%) with favorable results, depending on location, and two combinations (5.7%) with unfavorable results at both locations. These results suggest that there would be mostly no effect or positive biologically meaningful temperature-related effects of Alternative 2 Without TUCP Delta VA on winter-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River, although there were some negligible negative effects on egg incubation and fry emergence below Clear Creek.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 42.1°F to 55°F range for spawning initiation, there were five to 10 month-water year type combinations (14.3% to 28.6%) with favorable results, depending on location, and no combinations (0% of total combinations during the period) with unfavorable results (Table O-31). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were two to five combinations (5.7% to 14.3%) with favorable results, depending on location, and two combinations (5.7%) with unfavorable results below Keswick Dam and below Clear Creek. These results suggest that there would be mostly no effect or positive biologically meaningful temperature-related effects of Alternative 2 Without TUCP Systemwide VAs on winter-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River, although there were some negligible negative effects on egg incubation and fry emergence at both locations.

Overall, the four phases of Alternative 2 would have similar water temperature-related effects to winter-run Chinook salmon spawning and egg/incubation in the Sacramento River relative to the No Action Alternative. All four phases would have mostly no effect or positive effects with some negligible negative effects specific to egg incubation and fry emergence (Table O-31).

Summary

Alternative 2 relative to the No Action Alternative is expected to have possible minor beneficial to minor adverse impacts on spawning and redd dewatering habitat, possible beneficial and adverse impacts on spawner abundance, no impact on female escapement other than a minimal beneficial impact under Alternative 2 With TUCP Without VA, and a beneficial impact on the probability of quasi-extinction due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have possible slight to substantial beneficial impacts using four secondary biological models due to differences in water temperature: IOS, Anderson and Martin (TDM), and OBAN. Alternative 2 and the No Action Alternative using a coarser analysis is expected to have mostly no or beneficial impact on spawning and egg/alevin incubation with negligible adverse impacts specific to egg incubation and fry emergence.

Juvenile Rearing and Emigration

Winter-run Chinook salmon juveniles rear in the Sacramento River primarily from late summer to late winter and emigrate from the river to the Delta beginning in November (see Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). The proportion of juveniles surviving to emigrate to the Delta depends largely on habitat conditions, including flow and water temperature. Inundated floodplain habitat has been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001a, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under the four phases of Alternative 2, mean fry rearing WUA generally decreases in wet, above normal, below normal water year types and fluctuate depending on the phase in dry and critically dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between the four phases of Alternative 2 and the No Action Alternative is a 2.2% increase in critically dry water year types under Alternative 2 With TUCP Without VA. The largest reduction in estimated fry rearing habitat is a 0.8% decrease in below normal water year types between Alternative 2 Without TUCP with Systemwide VA and the No Action Alternative.

The monthly median values of fry rearing WUA under the four phases of Alternative 2 are similar to the No Action Alternative throughout the fry rearing period of August through December (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Fry rearing WUA median values for all the modeled alternatives are relatively similar across September through December but slightly lower in August. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in August in comparison to the other fry rearing months, with an average flow of 9,548 to 9,640 cfs under the four phases of Alternative 2 (Table O-182 through Table O-185). Segment 5, which has the highest distribution of winter-run spawning, has decreased WUA values when flows are between 5,000 and 10,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), leading to lower WUA values during higher flows in August. Winter-run Chinook salmon fry rearing WUA starts to increase at flows above 10,000 cfs, and peak at flows around 30,000 cfs. These peak rearing flows are not expected to occur under the No Action Alternative or the four phases of Alternative 2 during the fry rearing period in the Sacramento River below Keswick Dam. Winter-run Chinook salmon is the only Sacramento River salmonid race or species that shows this pattern.

The results of the winter-run Chinook salmon fry rearing habitat analysis suggest that the four phases of Alternative 2 may have a minor (less than 2.5%) increase and/or decrease in estimated fry rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Juvenile Rearing Habitat Analyses

Under the four phases of Alternative 2, mean juvenile rearing WUA increases depending on the phase in critically dry water year types but generally decreases in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat between Alternative 2 and the No Action Alternative is a 0.7% increase in critically dry water years under Alternative 2 With TUCP Without VA. The largest reduction in estimated juvenile rearing habitat is a 0.5 % decrease in below normal water year types under Alternative 2 Without TUCP Systemwide VA.

The monthly median value of juvenile rearing WUA under the four phases of Alternative 2 are similar to the No Action Alternative October through January (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Juvenile rearing WUA median values for all the modeled alternatives are relatively similar October through January. The CalSim 3 simulated average

flows in the Sacramento River below Keswick Dam are higher in January compared to the other months of juvenile rearing (Table O-182 through Table O-185). Segment 5 has decreased WUA values when flows are between 5,000 and 10,000 cfs but the WUA values do not change as drastically with juvenile rearing in comparison to fry rearing (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Winter-run Chinook salmon juvenile rearing WUA values start increasing at flows above 15,000 cfs, and peak at flows around 30,000 cfs. These peak rearing flows are not expected to occur under the No Action Alternative or the four phases of Alternative 2 during the juvenile rearing period in the Sacramento River below Keswick Dam.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for winter-run Chinook salmon in the upper Sacramento River under the four phases of Alternative 2 have a -0.4% to -2% difference between the months of October through January in comparison to the No Action Alternative (Attachment O.2*, CVPIA SIT LCM Habitat Estimates*). No monthly average increases to habitat are expected October through January under the phases of Alternative 2, and the greatest reductions in estimated habitat are expected in January under Alternative 2 With and without TUCP Without VA compared to the No Action Alternative.

The results of the two winter-run Chinook salmon juvenile rearing habitat analyses suggest that the four phases of Alternative 2 may have a negligible (less than 1%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and potentially no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles who primarily are stronger swimmers. The four phases or Alternative 2 show little difference in stranding of winter-run Chinook salmon juveniles between critically dry and dry water year types or between below normal and above normal water year types, but show much lower stranding for wet water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Winter-run fry rearing occurs primarily during summer through early fall, when flows tend to be less variable. The minimum rates of stranding for winter-run Chinook salmon fry during wet years may result from increased stability in project operations related to greater reservoir storage levels. Median stranding of all alternatives gradually increases from July through October (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). All four phases of Alternative 2 have substantially lower juvenile stranding of winter-run Chinook salmon fry than the No Action Alternative (12% to 15% lower) in below normal water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). All phases of Alternative 2 also have large reductions (8.4% to 9.7%) in critically dry water years, except Alternative 2 Without TUCP Without VA, which has the only notable increase (3.5%) of the four phases and water year types. Overall, winter-run juvenile stranding for fry is generally lower under the four phases of Alternative 2 in comparison to the No Action Alternative, including some substantial reduction. Overall, juvenile stranding for winter-run Chinook salmon fry is lower under the four phases of Alternative 2 than under the No Action Alternative.

Survival and Travel Time: XT and Flow Survival Threshold Models

Del Rosario et al. (2013) found that ≥5% catch at the Knights Landing Rotary Screw Trap (RST) coincided with first day of flow of at least ~14,100 cfs (400 cm) at Wilkins Slough. Acoustically tagged fish released at locations in the upper Sacramento River under varying hydrological conditions are used to estimate survival probabilities and travel times rates. As fish migrate downstream towards the Delta, individuals encounter a range of environmental conditions and transition from reaches with unidirectional flow (upstream) to reaches with bidirectional flow (tidally driven, downstream). Outmigrating juveniles may be exposed to predation and as inflow declines and tidal influence moves upstream, travel time and distance may increase leading to higher exposure to predators. Michel et al. (2021) identified an optimal flow threshold condition favorable for outmigration for juvenile Chinook salmon, 10,712 cfs, which could provide an additional 2.7-fold increase in survival. Travel and survival rates of Chinook salmon in upper Sacramento River reaches are strongly correlated (Notch et al. 2020). Authors hypothesize one mechanism for the threshold is faster outmigration rates due to higher flows decrease exposure to possible predation (Michel et al. 2021).

Differences in daily flows (Upper Sacramento River Daily Operations Model, USRDOM) under all four phases of Alternative 2 compared with the No Action Alternative may have effects on juvenile Chinook salmon's travel time and survival probabilities in the Upper Sacramento River. These possible differences were evaluated using several quantitative models (XT and Flow Survival Threshold) and results from all four phases are presented below by phase.

- **Alternative 2 Without TUCP Without VA**
    - Mean daily Sacramento River flows at Keswick Dam and mean daily Sacramento River flows below Wilkins Slough (March 15th to June 15th) are equal to or greater under Alternative 2 Without TUCP Without VA compared with the No Action Alternative except during May and June at Keswick Dam in critically dry water year types when flows are less under Alternative 2 Without TUCP Without VA compared with the No Action Alternative (Attachment J.4, *XT Model*; Attachment J.5, *Flow Threshold Salmon Survival Model*). These two quantitative models provide results that demonstrate the flows under Alternative 2 Without TUCP Without VA compared with the No Action Alternative could increase survival and decrease travel time for outmigrating juvenile Chinook salmon on the Sacramento River limiting juveniles' exposure to predation and poor environmental conditions.
    - Annual mean survival probability under Alternative 2 Without TUCP Without VA was greater than annual mean survival probability under the No Action Alternative in all water year types (5% to 6% greater in wet and above normal water year types to up to 95% greater in critically dry water year types). This increase, particularly in critically dry water year types of up to 95%, would have a substantial beneficial effect on outmigrating juvenile Chinook salmon. Under both scenarios, average annual mean survival probability was highest during the wet water year types and decreased as the water year type became drier. (Attachment J.5, *Flow Threshold Salmon Survival Model*).

- Mean survival probability for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 2 Without TUCP Without VA was equal to or greater than mean survival probability under the No Action Alternative (equal in wet, above normal, and below normal water year types and to up to 3% greater in dry and critically dry water year types). This increase of up to 3% would have a minimal effect on outmigrating juvenile Chinook salmon. (Attachment J.4, *XT Model*).

- Mean travel time (days) for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 2 Without TUCP Without VA was both greater than and less than mean travel time under the No Action Alternative (up to 2% greater during below normal and above normal water year types to the terminus of both reaches, 5% less during the dry water year type, and up to 10% less under critically dry water year type). This decrease of up to 10% would have a beneficial effect on outmigrating juvenile Chinook salmon, particularly dependent on predator presence and environmental conditions (e.g., water temperature) (Attachment J.4, *XT Model*).

- **Alternative 2 With TUCP Without VA**

  - Mean daily Sacramento River flows at Keswick Dam and mean daily Sacramento River flows below Wilkins Slough (March 15th to June 15th) are equal to or greater under Alternative 2 With TUCP Without VA compared with the No Action Alternative except during May and June at Keswick Dam in critically dry water year types when flows are less under Alternative 2 With TUCP Without VA compared with the No Action Alternative (Attachment J.4, *XT Model*; Attachment J.5, *Flow Threshold Salmon Survival Model*). These two quantitative models provide results that demonstrate the flows under Alternative 2 With TUCP Without VA compared with the No Action Alternative could increase survival and decrease travel time for outmigrating juvenile Chinook salmon on the Sacramento River limiting juveniles' exposure to predation and poor environmental conditions.

  - Annual mean survival probability under Alternative 2 With TUCP Without VA was greater than annual mean survival probability under the No Action Alternative in all water year types (5% to 6% greater in wet and above normal water year types to up to 22% greater in dry and critically dry water year types). This increase, particularly in dry and critically dry water year types of up to 22%, would have a large beneficial effect on outmigrating juvenile Chinook salmon. Under both scenarios, average annual mean survival probability was highest during the wet water year types and decreased as the water year type became drier. (Attachment J.5, *Flow Threshold Salmon Survival Model*).

- Mean survival probability for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 2 With TUCP Without VA was equal to or greater than mean survival probability under the No Action Alternative (equal in wet, above normal, below normal, and critically dry water year types and to up to 1% greater in dry water year types). This increase of up to 1% would have no effect on outmigrating juvenile Chinook salmon. (Attachment J.4, *XT Model*).

- Mean travel time (days) for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 2 With TUCP Without VA was both greater than and less than mean travel time under the No Action Alternative (equal in wet water years to the terminus of both reaches, up to 5% less in dry water year type to the terminus of both reaches, and up to 1% greater to the terminus of both reaches in Critically Dry water years). This decrease of up to 5% may have a beneficial effect on outmigrating juvenile Chinook salmon, particularly dependent on predator presence and environmental conditions (e.g., water temperature) (Attachment J.4, *XT Model*).

- **Alternative 2 Without TUCP Delta VA**

  - Mean daily Sacramento River flows at Keswick Dam and mean daily Sacramento River flows below Wilkins Slough (March 15th to June 15th) are equal to or greater under Alternative 2 Without TUCP Delta VA compared with the No Action Alternative except during May and June at Keswick Dam in critically dry water year types when flows are less under Alternative 2 Without TUCP Delta VA compared with the No Action Alternative (Attachment J.4, *XT Model*; Attachment J.5, *Flow Threshold Salmon Survival Model*). These two quantitative models provide results that demonstrate the flows under Alternative 2 Without TUCP Delta VA compared with the No Action Alternative could increase survival and decrease travel time for outmigrating juvenile Chinook salmon on the Sacramento River limiting juveniles' exposure to predation and poor environmental conditions.

  - Annual mean survival probability under Alternative 2 Without TUCP Delta VA was greater than annual mean survival probability under the No Action Alternative in wet, above normal, and critically dry water year types (4% greater in wet water year types and up to 70% greater in critically dry water year types). Annual mean survival probability under Alternative 2 Without TUCP Delta VA was less than annual mean survival probability under the No Action Alternative in below normal and dry water year types (up to 1.5% in dry water year types). The decrease would have a minimal adverse effect while the increase of up to 70% would have substantial beneficial effect on outmigrating juvenile Chinook salmon. Under both scenarios, average annual mean survival probability was highest during the wet water year types and decreased as the water year type became drier. (Attachment J.5, *Flow Threshold Salmon Survival Model*).

- Mean survival probability for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 2 Without TUCP Delta VA was equal to or greater than mean survival probability under the No Action Alternative (equal in wet, above normal, below normal, and dry water year types and to up to 1% greater in critically dry water year types). This increase of up to 1% would have no effect on outmigrating juvenile Chinook salmon. (Attachment J.4, *XT Model*).

- Mean travel time (days) for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 2 Without TUCP Delta VA was both greater than and less than mean travel time under the No Action Alternative (up to 1% greater under above normal and dry water year types to the terminus of both reaches and 3% less under critically dry water year type to the terminus of both reaches). This decrease of up to 3% may have a minor beneficial effect on outmigrating juvenile winter-run Chinook salmon, particularly dependent on predator presence and environmental conditions (e.g., water temperature) (Attachment J.4, *XT Model*).

- **Alternative 2 Without TUCP Systemwide VA**

  - Mean daily Sacramento River flows at Keswick Dam and mean daily Sacramento River flows below Wilkins Slough (March 15th to June 15th) are equal to or greater under Alternative 2 Without TUCP Systemwide VA compared with the No Action Alternative except during May and June at Keswick Dam in dry and critically dry water year types when flows are less under Alternative 2 Without TUCP Systemwide VA compared with the No Action Alternative (Attachment J.4, *XT Model*; Attachment J.5, *Flow Threshold Salmon Survival Model*). These two quantitative models provide results that demonstrate the flows under Alternative 2 Without TUCP Systemwide VA compared with the No Action Alternative could increase survival and decrease travel time for outmigrating juvenile Chinook salmon on the Sacramento River limiting juveniles' exposure to predation and poor environmental conditions.

  - Annual mean survival probability under Alternative 2 Without TUCP Systemwide VA was greater than annual mean survival probability under the No Action Alternative in all water year types (1% greater in dry water year types and up to 71% greater in critically dry water year types). The increase would have a minimal to substantial beneficial effect, depending on water year type, on outmigrating juvenile Chinook salmon. Under both scenarios, average annual mean survival probability was highest during the wet water year types and decreased as the water year type became drier. (Attachment J.5, *Flow Threshold Salmon Survival Model*).

- Mean survival probability for outmigrating winter-run Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 2 Without TUCP Systemwide VA was equal to or greater than mean survival probability under the No Action Alternative (equal in wet, above normal, and dry water year types and to up to 1% greater in below normal and critically dry water year types). This increase of up to 1% would have no effect on outmigrating juvenile winter-run Chinook salmon. (Attachment J.4, *XT Model*).

- Mean travel time (days) for outmigrating winter-run Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 2 Without TUCP Systemwide VA was both greater than and less than mean travel time under the No Action Alternative (2% greater under dry water year type to the terminus of both reaches and up to 4% less under below normal water year type to the terminus of both reaches). This decrease of 4% may have a beneficial effect on outmigrating juvenile winter-run Chinook salmon, particularly dependent on predator presence and environmental conditions (e.g., water temperature) (Attachment J.4, *XT Model*).

<u>Winter-run Juvenile Production Index (JPI)</u>

- Under **Alternative 2 With TUCP Without VA**, the mean predicted JPI is generally lower than No Action Alternative, ranging from 4.45% higher in 2005 to 29.91% lower in 2014. JPI under Alternative 2 With TUCP Delta VA was lower than the No Action Alternative in all but four years analyzed (2002-2021). These results suggest that in most years the benefits to juvenile winter-run Chinook salmon under Alternative 2 With TUCP Without VA were adverse and in a smaller number of years the effects are not noticeably different when compared to the No Action Alternative. Overall, Alternative 2 With TUCP Without VA is expected to have a negative effect on the number of juveniles produced annually when compared to the No Action Alternative.

- Under **Alternative 2 Without TUCP Without VA**, the mean predicted JPI is generally lower than No Action Alternative, ranging from 10.95% higher in 2015 to 53.08% lower in 2014. JPI under Alternative 2 Without TUCP without Delta VA was lower than the No Action Alternative in all but four years analyzed. These results suggest that in most years the benefits to juvenile winter-run Chinook salmon under Alternative 2 Without TUCP Without VA were adverse and in a smaller number of years the effects are not noticeably different when compared to the No Action Alternative. Overall, Alternative 2 Without TUCP Without VA is expected to have a negative effect on the number of juveniles produced annually when compared to the No Action Alternative.

- Under **Alternative 2 Without TUCP Delta VA**, the mean predicted JPI is generally higher than No Action Alternative, ranging from 272.52% higher in 2014 to 85.00% lower in 2017. JPI under Alternative 2 Without TUCP Delta VA was higher than the No Action Alternative in half of the years analyzed. These results suggest that in half of the years the benefits to juvenile winter-run Chinook salmon under Alternative 2 Without

TUCP Delta VA were adverse and in half the number of years the effects are beneficial when compared to the No Action Alternative due to three years showing very large increases, 272.52% (2014), 100.63% (2020), and 108.00% (2015). Overall, Alternative 2 Without TUCP Delta VA is expected to have a positive effect on the number of juveniles produced annually when compared to the No Action Alternative.

- Under **Alternative 2 Without TUCP Systemwide VA**, the mean predicted JPI is generally lower than No Action Alternative, ranging from 3.60% higher in 2005 to 30.68% lower in 2014. JPI under Alternative 2 Without TUCP Systemwide VA was lower than the No Action Alternative in all but one year analyzed. These results suggest that in most years the impacts to juvenile winter-run Chinook salmon under Alternative 2 Without TUCP Systemwide VA were adverse and in one year the impacts are not noticeably different when compared to the No Action Alternative. Overall, Alternative 2 Without TUCP Systemwide VA is expected to have a negative impact on the number of juveniles produced annually when compared to the No Action Alternative.

<u>IOS: Fry Survival and Juvenile River Migration Survival</u>

- Under **Alternative 2 With TUCP Without VA**, in critically dry water years, mean predicted winter-run Chinook salmon fry survival is 21.92% higher than when compared to the No Action Alternative. Alternative 2 With TUCP Without VA reflects a change of 0.142 mean predicted winter-run Chinook salmon fry survival when compared to the No Action Alternative (0.65 under the No Action Alternative to 0.794 under Alternative 2 With TUCP Without VA). The change in mean predicted winter-run Chinook salmon fry survival in all other water year types was less than or equal to ± 0.002. Alternative 2 With TUCP Without VA provides a substantial benefit to predicted survival of winter-run Chinook salmon fry during critically dry water years when compared to the No Action Alternative.

- Under **Alternative 2 Without TUCP Without VA**, in critically dry water years, mean predicted winter-run Chinook salmon fry survival is 5.89% lower than when compared to the No Action Alternative. However, the change in mean predicted winter-run Chinook salmon fry survival in all water year types was less than or equal to ± 0.00. There is not a substantial difference in predicted survival of winter-run Chinook salmon eggs between Alternative 2 Without TUCP Without VA and the No Action Alternative.

- Under **Alternative 2 Without TUCP Delta VA**, in critically dry water years, mean predicted winter-run Chinook salmon fry survival is 6.47% lower than when compared to the No Action Alternative. However, the change in mean predicted winter-run Chinook salmon fry survival in all water year types less than or equal to ± 0.04. There is not a substantial difference in predicted survival of winter-run Chinook salmon fry between Alternative 2 Without TUCP Delta VA, and the No Action Alternative.

- Under **Alternative 2 Without TUCP Systemwide VA**, in critically dry water years, mean predicted winter-run Chinook salmon fry survival is 9.25% lower than when compared to the No Action Alternative. Alternative 2 Without TUCP Systemwide VA reflects a change of -0.061 mean predicted winter-run Chinook salmon fry survival when compared to the No Action Alternative (0.652 under the No Action Alternative to 0.591 under Alternative 2 Without TUCP Systemwide VA). The change in mean predicted

winter-run Chinook salmon fry survival in all other water year was types less than or equal to ± 0.002. There is a slightly negative effect on survival of winter-run Chinook salmon fry between Alternative 2 Without TUCP Systemwide VA and the No Action Alternative.

- Under **Alternative 2 With TUCP Without VA**, in all water years, mean predicted river migration survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to 0.002. There is not a substantial difference in predicted river migration survival of winter-run Chinook salmon juveniles between Alternative 2 With TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Without VA**, in all water years except Below Normal, mean predicted river migration survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to ± 0.002. There is not a substantial difference in predicted river migration survival of winter-run Chinook salmon juveniles between Alternative 2 Without TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Delta VA**, in all water years except Below Normal, mean predicted river migration survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to ± 0.001. There is not a substantial difference in predicted river migration survival of winter-run Chinook salmon juveniles between Alternative 2 Without TUCP Delta VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Systemwide VA**, in all water years, mean predicted river migration survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to 0.001. There is not a substantial difference in predicted river migration survival of winter-run Chinook salmon juveniles between Alternative 2 Without TUCP Systemwide VA and the No Action Alternative.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 28 for Keswick Dam, Table 30 for Red Bluff Diversion Dam, and Table 32 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 34 for Keswick Dam, Table 36 for Red Bluff Diversion Dam, and Table 38 for Hamilton City.

Results for the two analyses are summarized in Table O-32. Table O-32, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 55.4°F to 68°F optimum temperature range analysis, there were zero to two month-water year type combinations with favorable results (0% to 6.7% of total combinations during the period), depending on location, and zero to two combinations (0% to 6.7%) with unfavorable results (Table O-32). For the 75.2°F upper incipient lethal temperature under Alternative 2 With TUCP Without VA, there would be no favorable or unfavorable results (0%) at any location. These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on water temperature conditions for winter-run Chinook salmon juvenile rearing and emigration in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 55.4°F to 68°F optimum temperature range analysis, there were zero to two month-water year type combinations with favorable results (0% to 6.7% of total combinations during the period), depending on location, and one to two combinations (3.3% to 6.7%) with unfavorable results (Table O-32). For the 75.2°F upper incipient lethal temperature under Alternative 2 Without TUCP Without VA, there would be no favorable or unfavorable results (0%) at any location. These results suggest that there would be negligible positive and negative effects of Alternative 2 Without TUCP Without VA on water temperature conditions for winter-run Chinook salmon juvenile rearing and emigration in the Sacramento River.
- Under **Alternative 2 Without TUCP Delta VA** for the 55.4°F to 68°F optimum temperature range analysis, there were one to four month-water year type combinations with favorable results (3.3% to 13.3% of total combinations during the period), depending on location, and zero to one combinations (0% to 3.3%) with unfavorable results (Table O-32). For the 75.2°F upper incipient lethal temperature Alternative 2 Without TUCP Delta VA, there would be no favorable or unfavorable results (0%) at any location. These results suggest that there would be positive effects of Alternative 2 Without TUCP Delta VA on water temperature conditions for winter-run Chinook salmon juvenile rearing and emigration in the Sacramento River.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 55.4°F to 68°F optimum water temperature range analysis, there were zero to two month-water year type combinations with favorable results (0% to 6.7% of total combinations during the period), depending on location, and zero to three combinations (0% to 10.0%) with unfavorable results (Table O-32). For the 75.2°F upper incipient lethal temperature under Alternative 2 Without TUCP Systemwide VAs, there would be no favorable or unfavorable results (0%) at any location. These results suggest that there would be positive and negative effects of Alternative 2 Without TUCP Systemwide VAs on water temperature conditions for winter-run Chinook salmon juvenile rearing and emigration in the Sacramento River.

Overall, Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP Systemwide VAs would have similar positive and negative water temperature-related effects to winter-run Chinook salmon juvenile rearing and outmigration in the Sacramento River (Table O-32). Alternative 2 Without TUCP Delta VA would have positive water temperature-related effects to winter-run Chinook salmon juvenile rearing and outmigration in the Sacramento River below Keswick Dam.

Summary

Alternative 2 and the No Action Alternative is expected to have possible minor beneficial to minor adverse impacts on fry and juvenile rearing habitat, a beneficial impact on fry stranding, and an adverse impact on the juvenile production index due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have possible little to minor adverse to beneficial impact on fry survival except under Alternative 2 With TUCP Without VA which is expected to have a substantial beneficial impact in critically dry water year type due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have a minimal to substantial beneficial impact, depending on water year type, on individuals' survival and travel time in the upper Sacramento River while Alternative 2 Without TUCP Delta VA could have a possible minimal adverse impact due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have beneficial and adverse water temperature-related impact on juvenile rearing and emigration.

Adult Upstream Migration and Holding

Winter-run Chinook salmon adults enter the Sacramento River from the Delta and make their way to the upper Sacramento River, beginning as early as December through late spring (May/June) (see Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). They hold in the upper River within 10 to 15 miles of Keswick Dam until they are ready to spawn, which may extend through August (Windell et al. 2017). Most of the run passes Red Bluff Diversion Dam from January to May with the peak in mid-March (Hallock and Fisher 1985).

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

CalSim 3 Flows

Releases from Shasta Reservoir during November through early May may be reduced to conserve water for the May through October winter-run Chinook salmon and spring-run Chinook salmon spawning and incubation periods, resulting in reduced flow in the middle Sacramento River. Lower flow in the Sacramento River relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of Winter-run adults into canals and behind weirs, increasing their stranding risk. Once the adults have migrated upstream on the Sacramento River, they reach holding habitat in the upper Sacramento River. In the upper Sacramento River, they are more directly affected by Shasta Reservoir and Keswick Dam operations designed to preserve cold water for the winter-run Chinook salmon and spring-run Chinook salmon spawning and incubation periods.

- **Alternative 2 With TUCP Without VA:** During the December through May/June period of adult winter-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 With TUCP Without VA at Sacramento River below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative, except in an increase in January of a critically dry water year type (up to 7% greater) and a decrease in May of dry and critically dry water year types (up to 13% less) at all three locations. At Sacramento River below Keswick Dam flows under Alternative 2 With TUCP Without VA would range from less than to greater than flows under the No Action Alternative, depending on month and water year type, generally greater than flows under the No Action Alternative December through February and generally similar to or less than flows under the No Action Alternative in March through June particularly in critically dry water year types. Flows at Hamilton City and Wilkins Slough under Alternative 2 With TUCP Without VA would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 2 With TUCP Without VA would be greater than 5,300 cfs at Wilkins Slough and greater than 7,500 cfs at Hamilton City (Table O-186, Table O-182, Table O-190, Table O-194).
- **Alternative 2 Without TUCP Without VA:** During the December through May/June period of adult winter-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Without VA at Sacramento River below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative, except an increase in April (up to 21% in a critical water year type) and a decrease in May and June (up to 6% less in a critically dry critically dry year type). At Sacramento River below Keswick Dam flows under Alternative 2 Without TUCP Without VA would range from less than to greater than flows under the No Action Alternative, depending on month and water year type, generally greater than flows under the No Action Alternative December through April (up to 25% greater in April of a critically dry water year type) and generally similar to or less than flows under the No Action Alternative May and June (up to 10% lower in May of a critically dry water year type). Flows at Hamilton City and Wilkins Slough under Alternative 2 Without TUCP Without VA would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 2 Without TUCP Without VA would be greater than 5,300 cfs at Wilkins Slough and greater than 7,500 cfs at Hamilton City (Table O-187, Table O-183, Table O-191, Table O-195).
- **Alternative 2 Without TUCP Delta VA:** During the December through May/June period of adult winter-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Delta VA at Sacramento River below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative, except an increase in April (up to 25% greater in a critically dry water year type) and a decrease in May and June (up to 6% less in dry and critically dry water year types). At Sacramento River below Keswick Dam flows under Alternative 2 Without TUCP Delta VA would range from less than to greater than flows under the No Action Alternative, depending on month and water year type, generally greater than flows under the No Action Alternative December through April (up to 30%

greater in April of a critically dry water year type) and generally similar to or less that flows under the No Action Alternative in May and June (up to 10% less in May of a critically dry water year type). Flows at Hamilton City and Wilkins Slough under Alternative 2 Without TUCP Delta VA would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 2 Without TUCP Delta VA would be greater than 5,300 cfs at Wilkins Slough and greater than 7,550 cfs at Hamilton City (Table O-188, Table O-184, Table O-192, Table O-196.

- **Alternative 2 Without TUCP Systemwide VA:** During the December through May/June period of adult winter-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Delta VA at Sacramento River below Red Bluff Diversion, below Keswick Dam, and at Wilkins Slough would range from less than to greater than flows under Alternative 2 Without TUCP Delta VA, depending on month and water year type, generally greater than flows under the No Action Alternative December through April (up to 23% greater in a critically dry water year type) and generally lower than flows under the No Action Alternative May and June (up to 8% lower in an above normal water year type). At Hamilton City flows under Alternative 2 Without TUCP Delta VA would generally be similar to flows under the No Action Alternative except April of most water year types (up to 29% greater) and June of most water year types (up to 8% less). Flows at Hamilton City and Wilkins Slough under Alternative 2 Without TUCP Systemwide VA would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 2 Without TUCP Systemwide VA would be greater than 5,100 cfs at Wilkins Slough and greater than 7,550 cfs at Hamilton City (Table O-189, Table O-185, Table O-193, Table O-197).

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range for winter-run Chinook salmon adult migration and holding are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 4 for Keswick Dam, Table 6 for Red Bluff Diversion Dam, and Table 8 for Hamilton City.

Results are summarized in Table O-33. Table O-33, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA**, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at all locations (Table O-33). These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on water temperature conditions for winter-run Chinook salmon adult migrants in the Sacramento River.

- Under **Alternative 2 Without TUCP Without VA**, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at all locations (Table O-33). These results suggest that there would be negligible effects of Alternative 2 Without TUCP Without VA on water temperature conditions for winter-run Chinook salmon adult migrants in the Sacramento River.

- Under **Alternative 2 Without TUCP Delta VA**, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at all locations (Table O-33). These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on water temperature conditions for winter-run Chinook salmon adult migrants in the Sacramento River.
- Under **Alternative 2 Without TUCP Systemwide VAs**, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at all locations, except Hamilton City, at which there was one combination (3.3%) with an unfavorable result (Table O-33). These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on water temperature conditions for winter-run Chinook salmon adult migrants in the Sacramento River.

Overall, all four phases would have negligible water temperature-related effects to winter-run Chinook salmon adult upstream migration and holding in the Sacramento River (Table O-33).

Summary

Alternative 2 relative to the No Action Alternative is expected to an adverse to beneficial flow-related impact, depending on location and month, generally a possible beneficial impact early in the season (December and January) and an adverse impact later in the season (May and June) on upstream migrating and holding adult winter-run Chinook salmon, average monthly flows at Hamilton City and Wilkins Slough are high enough to allow upstream passage. Alternative 2 and the No Action Alternative is expected to have a negligible water temperature-related impact on upstream migrating and holding adult winter-run Chinook salmon.

O.5.8.2 Bay-Delta

Juvenile Rearing and Emigration

Rearing winter-run Chinook salmon are present in the Delta from October to May (see Section O.1.9.1.1, *Winter-run Chinook Salmon, Sacramento River ESU*). Key habitat attributes relevant to seasonal operations in the Delta include out-migration cues and entrainment risk. Juveniles enter the Delta primarily during December through April and most emigrate past Chipps Island by the end of April but can potentially exit as late as May (Brandes and McLain 2001; del Rosario et al. 2013). A critical assumption in these analyses is LAD criteria used to identify juveniles (vs genetic ID) are sufficient to represent juveniles' downstream migration patterns.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to adversely affect juvenile Chinook salmon in two distinct ways: (1) "near-field" mortality associated with entrainment to the export facilities: and (2) "far-field" mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team's (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver-linkage-outcome (DLO) framework for specifying how water

project operations (the "driver") can influence juvenile salmonid behavior (the "linkage") and potentially cause changes in survival or routing (the "outcome"). The SST concluded altered "Channel Velocity" and altered "Flow Direction" were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O-13 provides a simplified conceptual model of the DLO defined by the CAMT SST.

Differences in hydrology in the Delta under the four phases of Alternative 2 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using two quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions.

Zone of Influence

For a full description of Zone of Influence model background, see *O.4.8.2 Sacramento River Winter-run Chinook Salmon ESU, Juvenile Rearing and Emigration in the Bay-Delta*. The following section covers discussion of differences in spatial extent of export influence presented as a direction between the four phases of Alternative 2 and the No Action Alternative. For a detailed explanation of methods and analyses, see Attachment I.3, *Delta Export Zone of Influence Analysis*.

The proportional overlap of two phases of Alternative 2 without VA (Alternative 2 With TUCP Without VA and without TUCP Without VA, pumping vs no pumping) was less than the proportional overlap of the No Action Alternative (pumping vs no pumping) at Turner Cut under all OMR bins (Attachment I.3, *Delta Export Zone of Influence Analysis*). The proportional overlap of the two phases of Alternative 2 with VA (Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA, pumping vs no pumping) was less than the proportional overlap of the No Action Alternative (pumping vs no pumping) at Turner Cut under all OMR bins except -3,500. The proportional overlap of all four phases of Alternative 2 (pumping vs no pumping) was less than the proportional overlap of the No Action Alternative (pumping vs no pumping) at Jersey Point under -2,000 and -5,000 OMR groupings; the same under < -5,500; and more under -3,500. The proportion al overlap of all four phases of Alternative 2 (pumping vs no pumping) was more than the proportional overlap of the No Action Alternative (pumping vs no pumping) at Old River at Middle River under all OMR bins except under the most positive OMR bins (-2,000).

With incremental decreases in OMR under all four phases of Alternative 2 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping.

Flow into Junctions

- Under **Alternative 2 With TUCP Without VA** in all OMR bins except -3,500, predicted proportion of flow entering the Central Valley Project (CVP) is less than the No Action Alternative. Changes in predicted proportion of flow entering the CVP when OMR was <-5,500, -5,000, and -3,500 were less than ± 0.03, indicating a negligible difference from the No Action Alternative. However, when OMR was -2,000 the change in predicted

proportion of flow into CVP was -0.069, indicating that slightly less flow will be routed into CVP under Alternative 2 With TUCP Without VA than when compared to the No Action Alternative.

- Under **Alternative 2 Without TUCP Without VA** in all OMR bins except -3,500, predicted proportion of flow entering the CVP is less than the No Action Alternative. Changes in predicted proportion of flow entering the CVP when OMR was <-5,500, -5,000, and -3,500 were less than ± 0.027, indicating a negligible difference from the No Action Alternative. However, when OMR was -2,000 the change in predicted proportion of flow into CVP was -0.0631, indicating that slightly less flow will be routed into CVP under Alternative 2 Without TUCP Without VA than when compared to the No Action Alternative.
- Under **Alternative 2 Without TUCP Delta VA** in all OMR bins except -3,500, predicted proportion of flow entering the CVP is less than the No Action Alternative. However, changes in predicted proportion of flow entering the CVP in all OMR bins was less than ± 0.0467, indicating a negligible difference between Alternative 2 Without TUCP Delta VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Systemwide VA** in all OMR bins except -3,500, predicted proportion of flow entering the CVP is less than the No Action Alternative. However, changes in predicted proportion of flow entering the CVP in all OMR bins was less than ± 0.0425, indicating a negligible difference between Alternative 2 Without TUCP Systemwide VA and the No Action Alternative.
- Under **Alternative 2 With TUCP Without VA** in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the HOR is less than the No Action Alternative. In OMR bins -3,500 and -5,000 predicted proportion of flow into the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.008, indicating a negligible difference between Alternative 2 With TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Without VA** in all OMR bins except <-5,500, predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.007, indicating a negligible difference between Alternative 2 Without TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Delta VA** in all OMR bins except <-5,500, predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.008, indicating a negligible difference between Alternative 2 Without TUCP Delta VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Systemwide VA** in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the HOR is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.008, indicating a negligible

difference between Alternative 2 Without TUCP Systemwide VA and the No Action Alternative.

Summary

Alternative 2 relative to the No Action Alternative is expected to influence flow into the HOR and CVP junctions due to differences in water management. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on flow into the HOR while differences at CVP are best described between phases of Alternative 2 with and without VA due to differences in flow: Alternative 2 With TUCP Without VA and without TUCP Without VA are expected to have slightly less flow into CVP at OMR -2,000 and Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA are expected to have negligible impacts on flow into CVP. Impacts of pumping under Alternative 2 relative to the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Winter-run Chinook Salmon

Differences in monthly flows on the Sacramento River under the four phases of Alternative 2 compared with the No Action Alternative may have effects on entrainment probability of juvenile Chinook salmon. These possible differences were evaluated using three quantitative models: Salvage Density, the Negative Binomial model, Coded Wire Tag Salvage.

Salvage Density and Negative Binomial

- **Alternative 2 With TUCP Without VAs**
    - Predictions from the salvage density model for genetic and LAD winter-run Chinook salmon include mean monthly total exports. Predictions from the negative binomial loss model for LAD winter-run Chinook salmon include mean monthly total exports and mean monthly San Joaquin River flows at Vernalis. Table O-202 shows modeled mean monthly total exports at SWP and CVP and Table O-242 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between the four phases of Alternative 2 and the No Action Alternative.
    - Predicted average monthly loss of genetic winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types. Alternative 2 With TUCP Without VAs was greater than or equal to predicted average monthly loss under the No Action Alternative for all water year types, up to 10% greater in critically dry water year types (Table O-36). Predicted average monthly loss of genetic winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for the wet and above normal water year types, up to 6% greater, for both wet and above normal water year types. Predicted salvage for LAD winter-run Chinook salmon was predicted to be lower for the below normal, dry and critically dry water year types, with up to 8% lower for the critically dry

water year types (Table O-37). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly loss of LAD winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through April of all water year types Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for some water year types, up to 2% greater in a above normal water year type, and up to 23% less for wet water year types compared to the No Action Alternative (Table O-34). Predicted average monthly loss of LAD winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for the wet and above normal water year types, up to 5% greater, for the above normal water year types. Predicted salvage for LAD winter-run Chinook salmon was predicted to be lower for the below normal, dry and critically dry water year types, with up to 7% lower for the critically dry water year types (Table O-35). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of LAD winter-run Chinook salmon at the Delta fish collection facilities for the months of December through April under Alternative 2 With TUCP Without VAs was greater than predicted average monthly salvage under the No Action Alternative for wet, above normal, and below normal water year types with up to 20% greater in a wet water year type. Predicted loss for genetic and LAD winter-run Chinook salmon under Alternative 2 With TUCP Without VAs compared to the No Action Alternative was less for dry and critically dry water year types, with up to an 8% reduction in loss for the critically dry water year types (Table O-38). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

- **Alternative 2 Without TUCP Without VAs**

  - Mean monthly total exports at SWP and CVP are equal to or greater under Alternative 2 Without TUCP Without VAs compared with the No Action Alternative for the full simulation period and all months December through May. Table O-203 shows modeled mean monthly total exports at SWP and CVP and Table O-243 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between the four phases of Alternative 2 and the No Action Alternative.

  - Predicted average monthly loss of genetic winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types. Alternative 2 Without TUCP Without VAs was less than or equal to predicted average monthly loss under the No Action Alternative for all water year types, except for the above normal water year types with an increase of 1%. Predicted loss from Alternative 2 Without TUCP Without VAs compared to the No Action Alternative was equal or lower for genetic winter-run Chinook salmon

with up to a 12% reduction in predicted loss for critically dry water year types (Table O-36). Predicted average monthly loss of genetic winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for the wet, above normal, and below normal water year types, with up to a 5% increase for above normal water year types. Predicted salvage for LAD winter-run Chinook salmon was predicted to be lower for the dry and critically dry water year types, with up to 8% lower for the critically dry water year types (Table O-37). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly loss of LAD winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through April of all water year types Alternative 2 Without TUCP Without VAs was less than or equal to predicted average monthly loss under the No Action Alternative for all water year types, except for the above normal water year types with an increase of 1%. Predicted loss from Alternative 2 Without TUCP Without VAs compared to the No Action Alternative was equal or lower for LAD winter-run Chinook salmon with up to a 12% reduction in predicted loss for critically dry water year types (Table O-34). Predicted average monthly loss of LAD winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for the wet, above normal, and below normal water year types, with up to a 5% increase for the above normal water year types. Predicted salvage for LAD winter-run Chinook salmon was predicted to be lower for the dry and critically dry water year types, with up to a 8% reduction in predicted loss for the critically dry water year types (Table O-35). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of LAD winter-run Chinook salmon at the Delta fish collection facilities for the months of December through April under Alternative 2 Without TUCP Without VAs was greater than predicted average monthly salvage under the No Action Alternative for wet, above normal, and below normal water year types with up to 20% greater in a wet water year type. Predicted loss for genetic and LAD winter-run Chinook salmon under Alternative 2 Without TUCP Without VA compared to the No Action Alternative was less for dry and critically dry water year types, with up to a 14% reduction in loss for the critically dry water year types (Table O-38). For detailed information on average monthly salvage by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- **Alternative 2 Without TUCP With Delta VAs**

- Mean monthly total exports at SWP and CVP had a wide range under Alternative 2 Without TUCP with Delta VAs compared with the No Action Alternative for the full simulation period and all months December through May. Table O-204 shows modeled mean monthly total exports at SWP and CVP and Table O-244 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between the four phases of Alternative 2 and the No Action Alternative.

- Predicted average monthly loss of genetic winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types. Alternative 2 Without TUCP with Delta VAs was less than predicted average monthly loss under the No Action Alternative for all water year types, except for the wet water year types with an increase of 4%. Predicted loss from Alternative 2 Without TUCP with Delta VAs compared to the No Action Alternative was lower for genetic winter-run Chinook salmon for all other water year types with up to a 23% reduction in predicted loss for below normal water year types (Table O-36). Predicted average monthly loss of genetic winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April for Alternative 2 Without TUCP with Delta VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types except the wet water year type, with up to a 2% increase. Predicted salvage for genetic winter-run Chinook salmon was predicted to be lower for Alternative 2 Without TUCP with Delta VAs for all other water year types, with up to 24% lower for the critically dry water year types (Table O-37). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly loss of LAD winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through April of all water year types. Alternative 2 Without TUCP with Delta VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types. Predicted loss of LAD winter-run Chinook salmon from Alternative 2 Without TUCP with Delta VAs compared to the No Action Alternative had a reduction of up to 16% for dry water year types (Table O-34). Predicted average monthly loss of LAD winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 2 Without TUCP with Delta VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types except for wet water year types, which had a 1% increase. Predicted salvage for LAD winter-run Chinook salmon at Jones under Alternative 2 Without TUCP with Delta VAs compared to the No Action Alternative was predicted to be lower for all other water year types, with up to a 16% reduction in predicted loss for the below normal water year types (Table O-35). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of LAD winter-run Chinook salmon at the Delta fish collection facilities for the months of December through April under Alternative 2 Without TUCP with Delta VAs was lower than predicted average monthly salvage under the No Action Alternative for all water year types except for wet water year types which had an increase of 13%. Predicted loss for genetic and LAD winter-run Chinook salmon under Alternative 2 Without TUCP with Delta VAs compared to the No Action Alternative was less for all other water year types, with up to a 25% reduction in loss for the below normal water year types (Table O-38). For detailed information on average monthly salvage by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- **Alternative 2 Without TUCP Systemwide VAs**

  - Mean monthly total exports at SWP and CVP had a wide range under Alternative 2 Without TUCP Systemwide VAs compared with the No Action Alternative for the full simulation period and all months December through May. Table O-205 shows modeled mean monthly total exports at SWP and CVP and Table O-245 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between the four phases of Alternative 2 and the No Action Alternative.

  - Predicted average monthly loss of genetic winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types. Alternative 2 Without TUCP Systemwide VAs was less than predicted average monthly loss under the No Action Alternative for above normal, below normal, and dry water year types with up to a 21% reduction in predicted loss for below normal water year types. Predicted loss from Alternative 2 Without TUCP Systemwide VAs compared to the No Action Alternative for genetic winter-run Chinook salmon for wet and critically dry water year types increased with up to a 3% increase in predicted loss for wet water year types (Table O-36). Predicted average monthly loss of genetic winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April for Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types except the wet water year type, which had up to a 3% increase. Predicted salvage for genetic winter-run Chinook salmon was predicted to be lower for Alternative 2 Without TUCP Systemwide VAs for all other water year types, with up to 26% lower for the below normal water year types (Table O-37). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

  - Predicted average monthly loss of LAD winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through April of all water year types. Alternative 2 Without TUCP Systemwide VAs was lower or equal to predicted average monthly loss under the No Action Alternative for all water year types. Predicted loss of LAD winter-run Chinook salmon from Alternative 2 Without TUCP Systemwide VAs compared to the No Action Alternative had a reduction of up to 14% for dry water year types (Table O-34). Predicted average

monthly loss of LAD winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types except for wet water year types, which had a 2% increase. Predicted salvage for LAD winter-run Chinook salmon at Jones under Alternative 2 Without TUCP Systemwide VAs compared to the No Action Alternative was predicted to be lower for all other water year types, with up to a 17% reduction in predicted loss for the below normal water year types (Table O-35). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of LAD winter-run Chinook salmon at the Delta fish collection facilities for the months of December through April under Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly salvage under the No Action Alternative for all water year types except for wet water year types which had an increase of 11%. Predicted loss for genetic and LAD winter-run Chinook salmon under Alternative 2 Without TUCP Systemwide VAs compared to the No Action Alternative was less for all other water year types, with up to a 25% reduction in loss for the below normal water year types (Table O-38). For detailed information on average monthly salvage by water year type (Attachment I.2, *Salvage Density Model Loss Simulation*).

<u>Winter-run Chinook Salmon Coded Wire Tag Salvage Model</u>

The Winter-run Chinook Salmon Coded Wire Tag (CWT) Proportional Salvage Model was developed to estimate the fraction of juvenile winter-run Chinook salmon in the Delta predicted to be salvaged based on hydrologic conditions and fish size. To apply this model to hydrologic scenarios outside of those used to construct the model, we had to use a fixed number of winter-run Chinook salmon entering the Delta each month. The raw output of the model is the number of fish salvaged. However, we used the offset variable to convert this number to a proportion. In this way the model predicts the magnitude of salvage independent of the number of fish that may actually be in the Delta during a given month.

Predicted mean of annual and monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for all months October through May under Alternative 2 With TUCP Without VA in all water year types, is higher than the No Action Alternative (Attachment I.9, *Winter-run Chinook Salmon Coded Wire Tag Salvage Model*). Alternative 2 With TUCP Without VA is predicted to increase the number of fish salvaged when compared to the No Action Alternative, however all predicted proportion salvaged are less than ± 0.01 in all months and years. Overall, there is not a substantial difference in predicted proportion salvaged between Alternative 2 With TUCP Without VA and the No Action Alternative.

Predicted mean of annual and monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for all months October through May under Alternative 2 Without TUCP Delta VA, Alternative 2 Without TUCP Systemwide VA and Alternative 2 Without TUCP Without VA in all water year types, varied from positive to negative between months when compared to the No Action Alternative. Salvage is predicted to increase in wet years under Alternative 2 Without TUCP Delta VA, Alternative 2 Without TUCP Systemwide VA and Alternative 2 Without TUCP

Without VA when compared to the No Action Alternative, however all predicted proportion salvaged are less than ± 0.01 in all months and years. Overall, there is not a substantial difference in predicted proportion salvaged between Alternative 2 Without TUCP Delta VA, Alternative 2 Without TUCP Systemwide VA and Alternative 2 Without TUCP Without VA and the No Action Alternative.

Summary

Differences in flow between the phases of Alternative 2 relative to the No Action Alternative on entrainment of juvenile winter-run Chinook salmon in the Delta are best explained by grouping the four phases into with VA (Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA) and without VA (Alternative 2 Without TUCP Without VA and with TUCP Without VA). Generally, the Alternative 2 with VA are expected to have an overall beneficial impact compared to the No Action Alternative with the exception of during a wet water year type. Generally, the Alternative 2 without VA could have an adverse to beneficial impact compared to the No Action Alternative depending on water year type and quantitative model, both types of impact could be large. Alternative 2 relative to the No Action Alternative is not expected to have an impact on the salvage proportion of juvenile winter-run Chinook salmon.

Potential Changes to Routing of Winter-run Chinook Salmon

Winter-run Chinook salmon travel through different migratory pathways. Using a conceptual model, a single fish in any location could have arrived at that location via one of several pathways (Figure O-14). For example, a fish observed salvage could have arrived via one of many pathways (e.g., Sacramento Origin via the mainstem Sacramento then below Cache Slough, then South Delta or via the DCC and Central Delta then the South Delta). If a proportion of fish is higher down a migratory pathway documented as a route with higher survival rates for juvenile salmonids, then fish migrating through that route will likely have a better chance of surviving to the ocean than fish migrating through a sub-optimal route (e.g., experiencing potential entrainment into the Central Delta through the DCC or Georgiana Slough).

Empirical estimates of acoustically tagged late fall-run Chinook salmon from Coleman National Fish Hatchery (CNFH) tracked in December 2006, January and December 2007, and January 2008 experienced routing in the mainstem Sacramento from 35.2% to 49.8%, through Georgiana Slough 0% to 31.1%, and through the Sutter and Steamboat sloughs 19.8% to 41.4% (Perry 2010). Results suggest the proportion of fish entering each route generally follows river flow but is not always in agreement with the proportion of discharge entering that route, suggesting another parameter may affect fish routing. Release groups experienced different discharge and export conditions leading to wide ranges in routing probabilities. Other studies also report proportional flow is a strong predictor of route selection (Kemp et al. 2005; Cavallo et al. 2015; Romine et al. 2021). Additionally, variables like DCC gate status (open / closed) will change routing and survival probabilities for fish traveling along the mainstem Sacramento when they get to both Georgiana Slough and the DCC junctions. Newman and Brandes (2010) reported that exports affect routing of fish released in Georgiana Slough more than fish released at Ryde (upstream of Georgiana Slough on the Sacramento River) and the fraction of fish released in Georgiana Slough recovered at the fish collection facilities increased with increased exports.

Differences in monthly flows on the Sacramento River under the four phases of Alternative 2 compared with the No Action Alternative may have effects on juvenile Chinook salmon's routing

and survival probabilities in the Sacramento River. These possible differences were evaluated by phase using two quantitative models: STARS and ECO-PTM.

STARS

Average Sacramento River flows at Freeport December through February are similar under all four phases of Alternative 2 compared with the No Action Alternative. Freeport flows March through May are similar under three phases of Alternative 2 compared with the No Action Alternative, except for Alternative 2 Without TUCP Systemwide VA which has flows slightly greater than the No Action Alternative. The STARS model is responsive to modeled Freeport flows and daily operations of the DCC gates, both obtained from CalSim 3.

- **Alternative 2 With TUCP Without VA:** The STARS model provides predictions of routing and survival probabilities, in this section routing results are discussed. In the "survival" section survival results are discussed. Mean proportion of particles routed to the Interior Delta via either Georgiana Slough or the DCC), averaged across all water year types by month under Alternative 2 With TUCP Without VA was similar to the No Action Alternative (up to 0.5% greater in February to up to 1.7% less in April) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*).
- **Alternative 2 Without TUCP Without VA:** Mean proportion of particles routed to the Interior Delta via either Georgiana Slough or the DCC), averaged across all water year types by month under Alternative 2 Without TUCP Without VA was similar to the No Action Alternative (up to 0.5% greater in January and February and up to 0.4% less in April and December) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*).
- **Alternative 2 Without TUCP Delta VA:** Mean proportion of particles routed to the Interior Delta via either Georgiana Slough or the DCC), averaged across all water year types by month under Alternative 2 Without TUCP Delta VA was similar to the No Action Alternative (up to 0.5% greater in January and February and up to 1.7% less in April) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*.
- **Alternative 2 Without TUCP Systemwide VA:** Mean proportion of particles routed to the Interior Delta via either Georgiana Slough or the DCC), averaged across all water year types by month under Alternative 2 Without TUCP Systemwide VA was similar to or less than the No Action Alternative (up to 0.5% greater in January and February and up to 3.7% less in April) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*).

The minimal range of differences among months in routing of juvenile salmonids into the Interior Delta under three of the four phases of Alternative 2 would have no effect on outmigrating juveniles, and routing under Alternative 2 Without TUCP Systemwide VA may have a minimal beneficial effect, particularly in April.

ECO-PTM

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under all four phases of Alternative 2 ranged from less than the No Action Alternative (up to 7% less under -5,000 cfs under Alternative 2 Without TUCP Without VA and Alternative 2 with TUCP without VA) to greater than the No Action Alternative (up to 9% greater under -3,500 cfs under Alternative 2 Without TUCP Delta VA) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in the attachment. The decrease in routing to the Interior Delta could have a beneficial effect on outmigrating juveniles while the increase in routing could have an adverse impact on outmigrating juveniles.

Summary

Two flow-based quantitative models suggest depending on considered variables, flows under the four phases of Alternative 2 compared with the No Action Alternative may have minor adverse or minor beneficial impacts for outmigrating juvenile Chinook salmon in the winter and spring, dependent on OMR grouping.

Potential Changes to Through Delta Survival of Winter-run Chinook Salmon

Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. Juvenile Chinook salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010, 2018).

Differences in monthly flows on the Sacramento River under the four phases of Alternative 2 compared with the No Action Alternative may have effects on juvenile Chinook salmon's routing and survival probabilities in the Sacramento River. These possible differences were evaluated by phase using several quantitative models: STARS, ECO-PTM, Delta Passage Model, IOS, and OBAN.

STARS

Average Sacramento River flows at Freeport December through February are similar under all four phases of Alternative 2 compared with the No Action Alternative. Freeport flows March through May are similar under three phases of Alternative 2 compared with the No Action Alternative, excepting Alternative 2 Without TUCP Systemwide VA which has flows slightly greater than the No Action Alternative. The STARS model is responsive to modeled Freeport flows and daily operations of the DCC gates, both obtained from CalSim 3.

- **Alternative 2 With TUCP Without VA:** The STARS model provides predictions of routing and survival probabilities, in this section survival results are discussed. In the "routing" section routing results are discussed. Mean predicted through-Delta survival of particles across all routes, averaged across all water year types by month under Alternative 2 With TUCP Without VA ranged from greater than the No Action Alternative (up to 1% greater in April) to equal to the No Action Alternative (December, January, and February) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). This minimal change in survival would likely have no effect on outmigrating juveniles.

- **Alternative 2 Without TUCP Without VA:** Mean predicted through-Delta survival of particles across all routes, averaged across all water year types by month under Alternative 2 Without TUCP Without VA was equal to or greater than the No Action Alternative (up to 0.2% greater in December and April) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). This increase in survival could have a minimal beneficial effect on outmigrating juveniles, particularly in December and April.
- **Alternative 2 Without TUCP Delta VA:** Mean predicted through-Delta survival of particles across all routes, averaged across all water year types by month under Alternative 2 Without TUCP Delta VA ranged from greater than the No Action Alternative (up to 0.8% greater in April) to less than the No Action Alternative (December, January, and February, up to 0.2% less) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). This increase in survival, particularly in April, could have a minimal beneficial effect on outmigrating juveniles.
- **Alternative 2 Without TUCP Systemwide VA:** Mean predicted through-Delta survival of particles across all routes, averaged across all water year types by month under Alternative 2 Without TUCP Systemwide VA ranged from greater than the No Action Alternative (up to 3% greater in April) to less than the No Action Alternative (up to 0.2% less in December) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). This increase in survival, particularly in April, could have a beneficial effect on outmigrating juveniles.

The minimal range of differences among months in through-Delta survival of juvenile salmonids under three of the four phases of Alternative 2 would have minimal to no effect on outmigrating juveniles, and through-Delta survival under Alternative 2 Without TUCP Systemwide VA may have a beneficial effect, particularly in April.

<u>ECO-PTM</u>

Particles in ECO-PTM are released at Freeport on the Sacramento River on the first of the month between the months of December and March, to provide routing and survival estimates. ECO-PTM relies on hydrological inputs generated by CalSim 3 combined with swimming behaviors associated with the neutrally buoyant particles in ECO-PTM include upstream or downstream movement, holding behaviors, and swimming velocity. In this section, through-Delta survival estimates are discussed. In the "routing" section routing estimates to the Interior Delta results are discussed. To represent possible conditions in the Delta, results are binned and presented using OMR groupings: < -5,500 cfs; -5,000 cfs; -3,500 cfs; and -2,000 cfs.

Mean through-Delta percent survival December through March under the four phases of Alternative 2 were not as consistent among phases of Alternative 2 as ECO-PTM routing results were. Mean through-Delta survival under the phases with no VA, Alternative 2 Without TUCP Without VA and with TUCP Without VA, ranged from less than the No Action Alternative (up to 4% less under -2,000 cfs) to greater than the No Action Alternative (up to 4% greater under -5,000 cfs) (Attachment I.7, *ECO-PTM*). Mean through-Delta survival under the phases with VA, Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA, ranged from less than the No Action Alternative (up to 5% less under -3,500 cfs) to greater than the No Action Alternative (up to 18% greater under -2,000 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in the attachment. The increase in survival under some

OMR conditions under phases of Alternative 2 with VA could have a large beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have an adverse impact on outmigrating juveniles.

Delta Passage Model

The DPM simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River and estimates survival to Chipps Island. For this application, only survival of fish entering the Delta from the Sacramento River are evaluated. The DPM uses available time-series data and values taken from empirical studies or other sources to parameterize model relationships and inform uncertainty, thereby using the greatest amount of data available to dynamically simulate responses of smolt survival to changes in water management. (Attachment I.6, *Delta Passage Model*). The major model functions in the DPM are listed above in Alternative 1 (see *O.4.8.2*).

- Under **Alternative 2 With TUCP Without VA**, in all except critically dry and dry water year types, predicted mean survival of spring-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted survival to Chipps Island in all water year types less or equal to than ± 0.001. There is not a substantial difference in predicted proportion of spring-run Chinook salmon surviving to Chipps Island between Under Alternative 2 With TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Without VA**, in all except critically dry and dry water year types, predicted mean survival of winter-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative. However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.003. There is not a substantial difference in predicted proportion of winter-run Chinook salmon surviving to Chipps Island between Under Alternative 2 Without TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Delta VA**, in all except critically dry and dry water year types, predicted mean survival of winter-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative. However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.002. There is not a substantial difference in predicted proportion of winter-run Chinook salmon surviving to Chipps Island between Under Alternative 2 Without TUCP Delta VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Systemwide VA**, in all except wet water year types, predicted mean survival of winter-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative. However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.004. There is not a substantial difference in predicted proportion of winter-run Chinook salmon surviving to Chipps Island between Under Alternative 2 Without TUCP Systemwide VA and the No Action Alternative.

IOS: Through-Delta Survival

- Under **Alternative 2 With TUCP Without VA** in critically dry water years only, mean predicted through Delta survival of winter-run Chinook salmon juveniles is lower than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to ± .005. There is not a substantial difference in predicted through Delta survival of winter-run Chinook salmon juveniles between Alternative 2 With TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Without VA** in dry and wet water years only, mean predicted through Delta survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to ± .008. There is not a substantial difference in predicted through Delta survival of winter-run Chinook salmon juveniles between Alternative 2 Without TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Delta VA** in below normal and critical water years only, mean predicted through Delta survival of winter-run Chinook salmon juveniles is lower than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to ± .007. There is not a substantial difference in predicted through Delta survival of winter-run Chinook salmon juveniles between Alternative 2 Without TUCP Delta VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Systemwide VA** in below normal and critically dry water years only, mean predicted through Delta survival of winter-run Chinook salmon juveniles is lower than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to ± .008. There is not a substantial difference in predicted through Delta survival of winter-run Chinook salmon juveniles between Alternative 2 Without TUCP Systemwide VA and the No Action Alternative.

OBAN: Delta Survival

Delta survival for the phases of Alternative 2 are best described as phases of Alternative 2 grouped by Voluntary Agreements (with and without VA). Delta survival for the phases of Alternative 2 without VA (Alternative 2 Without TUCP Without VA and with TUCP Without VA) was less than under the No Action Alternative (1.2% less, Table O-30). This decrease would have a minimal adverse effect on outmigrating juvenile winter-run Chinook salmon. Delta survival for the phases of Alternative 2 with VA (Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA) was greater than under the No Action Alternative (0.5% – 0.8% greater, Table O-30). This increase would have a minimal beneficial effect on outmigrating juvenile winter-run Chinook salmon.

Summary

Alternative 2 relative to the No Action Alternative is expected to have a possible adverse or beneficial impact on survival of outmigrating juvenile winter-run Chinook salmon depending on secondary biological model, phase of Alternative 2, and OMR grouping due to differences in flow. Alternative 2 relative to the No Action Alternative may have no difference on outmigrating juveniles or minimal adverse to minimal beneficial impacts due to flow.

O.5.9 Central Valley Spring-run Chinook Salmon ESU

O.5.9.1 Sacramento River

Spawning and Egg/Alevin Incubation

Spring-run Chinook salmon adults spawn from August through October (Williams 2006) with peak spawning in September (see Section O.1.3.2). Monitoring spring-run spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from Fall-run Chinook salmon. Most Spring-run Chinook salmon spawning occurs between the Keswick Dam and Ball Ferry Bridge (NMFS 2017c). Fry emergence occurs up to three months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating Spring-run Chinook salmon eggs and alevins potentially occur from August through January, peaking in December.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under the four phases of Alternative 2, differences in mean spawning WUA vary depending on water year type but are below a 3% difference across all water year types and phases when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between the four phases of Alternative 2 and the No Action Alternative is a 2.9% increase in critically dry water year types for Alternative 2 With TUCP Without VA. The largest reduction in estimated spawning habitat is a -2.6% decrease in above normal water year types (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

For all three months of the spring-run spawning season, spawning WUA under the four phases of Alternative 2 are similar to that for the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA for all the modeled alternatives are substantially lower in August than in September or October. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in August than in the other two months (Table O-182 through Table O-185). This results in lower spawning WUA results because the fall-run spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), which were used to estimate spring-run spawning WUA, peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of suitable habitat availability analysis using the SIT LCM habitat models indicate that spawning habitat for spring-run in the upper Sacramento River may not a limiting factor under both the No Action Alternative and Alternative 2 (See Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The results of the two spawning habitat analyses based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 may have a minor (less than 3%) increase and/or decrease in estimated spawning habitat during above normal water year types when compared to the No Action Alternative, but that spawning habitat may not be a limiting factor for spring-run Chinook salmon in the mainstem upper Sacramento River.

SIT Spring-run Lifecycle Model: Spawner Abundance

In the CVPIA spring-run SIT life cycle model, mean spring-run Chinook salmon spawner abundance in the Central Valley under the four phases of Alternative 2 annual in Chinook salmon spawner abundances are similar to or slightly higher than the No Action Alternative in the Central Valley. The largest increase in abundance between the No Action Alternative and an Alternative 2 phase was 0.7% under Alternative 2 With TUCP Without VA. The results suggest no decreases in abundance under the four phases of Alternative 2. Over the full model run period (1980–1999), abundance under all phases of Alternative 2 was equal to abundance under the No Action Alternative. Overall, the spawner abundance predicted by the CVPIA Spring-run Chinook salmon life cycle model is expected to be similar under all phases of Alternative 2 and the No Action Alternative.

Redd Dewatering Analysis

Under the four phases of Alternative 2, the spring-run Chinook salmon redd dewatering results show a consistent reduction in redd dewatering potential from wet and above normal water year types to drier water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation is expected for spring-run Chinook salmon because their spawning occurs in the fall, with incubation extending into early winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier winters, flow fluctuations are reduced and fewer redds are potentially dewatered. Reductions in the estimates of redd dewatering potential from the No Action Alternative are larger and more frequent than increases, with a maximum reduction of 22.0% in critically dry water year types under Alternative 2 Without TUCP With Delta VA. The largest increase is 8.3% in above normal water years for Alternative 2 Without TUCP With Systemwide VA scenario. For individual months, redd dewatering is slightly lower for September spawning under the four phases of Alternative 2 than the No Action Alternative and is about the same for October spawning (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that redd dewatering potential under the four phases of Alternative 2 would mostly be smaller than under the No Action Alternative, especially in critically dry water years, but the means would be about 7% higher in above normal water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 48 for Keswick Dam and Table 50 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 54 for Keswick Dam and Table 56 for Red Bluff Diversion Dam. Full results of

the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during September through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 60 for Keswick Dam and Table 62 for Red Bluff Diversion Dam.

Results for the three analyses are summarized in Table O-39. Table O-39, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 42.1°F to 55°F spawning initiation range analysis, there were five and one month-water year type combinations (14.3% and 2.9% of total combinations during the period) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively, and there were two and zero combinations (5.7% and 0%,) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively(Table O-39). For the 59.9°F pathogen virulence threshold, there were zero and 14 combinations (0% and 40.0%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively, and there were no combinations with unfavorable results at either location. For the 42.8°F to 56°F range for egg incubation and fry emergence, there was one combination (2.9%) with favorable results at Red Bluff Diversion Dam and two combinations (5.7%) with unfavorable results below Keswick Dam. These results suggest that there would be positive water temperature-related effects of Alternative 2 With TUCP Without VA on spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 42.1°F to 55°F spawning initiation range analysis, there were six and one month-water year type combinations (17.1% and 2.9% of total combinations during the period) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively (Table O-39). There were two and zero combinations (5.7% and 0%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. For the 59.9°F pathogen virulence threshold, there were three and 13 combinations (8.6% and 37.1%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. There were zero combinations (0%) with favorable or unfavorable results below Keswick and at Red Bluff Diversion Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there was one combination (2.9%) with favorable and unfavorable results below Keswick Dam and at Red Bluff Diversion Dam. These results suggest that there would be positive water temperature-related effects of Alternative 2 Without TUCP Without VA on spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Delta VA** for the 42.1°F to 55°F spawning initiation range analysis, there were five and zero month-water year type combinations (14.3% and 0% of total combinations during the period) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively (Table O-39). There were three and zero combinations (8.6% and 0%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. For the 59.9°F pathogen virulence threshold, there were zero and 11 combinations (0% and 31.4%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. There were zero

combinations (0%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero and four combinations (0% and 11.4%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. There were three and zero combinations (8.6% and 0%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. These results suggest that there would be positive water temperature-related effects of Alternative 2 Without TUCP Delta VA on spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 42.1°F to 55°F spawning initiation range analysis, there were five and one month-water year type combinations (14.3% and 2.9% of total combinations during the period) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively (Table O-39). There were two and zero combinations (5.7% and 0%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. For the 59.9°F pathogen virulence threshold, there were zero and 11 combinations (0% and 31.4%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. There were one and zero combinations (2.9% and 0%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero and two combinations (0% and 5.7%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. There were two and zero combinations (5.7% and 0%, respectively) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. These results suggest that there would be positive water temperature-related effects of Alternative 2 Without TUCP Systemwide VA on spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

Overall, the four phases of Alternative 2 would have similar positive and negative water temperature-related effects to spring-run Chinook salmon spawning and egg/incubation in the Sacramento River (Table O-39).

Summary

Alternative 2 relative to the No Action Alternative is largely expected to have little impact on spring-run Chinook salmon spawning and egg/alevin incubation (mortality) due to flow. There are no expected impacts to spawner abundance under Alternative 2. Flow for spawning habitat is not a limiting factor for spring-run Chinook salmon. Redd dewatering is decreased under Alternative 2 relative to the No Action Alternative, except in above normal water year types where the mean is about 7% higher. Water temperatures for spawning initiation are beneficial and adverse in the Sacramento River. Egg/incubation and fry emergence are similar or more beneficial under Alternative 2 relative to the No Action Alternative. Water temperatures for adult pathogen virulence is beneficial at Red Bluff Diversion Dam under all phases.

Juvenile–Yearling Rearing and Emigration

Spring-run Chinook salmon juveniles rear in the Sacramento River primarily from November through June and most emigrate to the Delta during December and again in March and April (Roberts 2007) (see Section O.1.3.2, Spring-run Chinook Salmon). Migratory cues, such as increased flow and/or turbidity from runoff, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (National Marine Fisheries Service 2009a). Inundated floodplain habitats have been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001a, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under the four phases of Alternative 2, mean fry rearing WUA decreases in all water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). There are no expected increases in estimated fry rearing habitat between the four phases of Alternative 2 and the No Action Alternative. The largest reduction in estimated fry rearing habitat is a 2.6% decrease in critically dry water year types under Alternative 2 Without TUCP with Systemwide VA and Alternative 2 Without TUCP with Delta VA in comparison to the No Action Alternative.

There are some differences in fry rearing WUA on a monthly scale between the four phases of Alternative 2 and the No Action Alternative. In April, there may be an 8% reduction in the median value of estimated fry rearing WUA under Alternative 2 Without TUCP with Systemwide VA, and a 7% reduction under Alternative 2 Without TUCP with Delta VA in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The four phases of Alternative 2 and the No Action Alternative are similar during the other fry rearing months. Estimated fry rearing WUA median values for all the modeled alternatives are similar across December, January, and March, which are important months for rearing. The results during these three months show little variation in the third quartile of the WUA distributions. This occurs because the fry rearing WUA curves peak at the lowest flows encountered in the river (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and Keswick Dam flow releases are frequently low during these months in critically dry years when Shasta Reservoir is operated to rebuild storage volume (Table O-182 through Table O-185). The first quartile is much wider because a greater range of flows affect the fry rearing WUA values below the median. November and April have the lowest median WUA values across all alternatives. The occurrence of some higher rearing WUA values for April results from the installation of the ACID dam for that month, which results in higher WUA values in Segment 6 of the river.

The results of the spring-run Chinook salmon fry rearing habitat analysis suggest that the four phases of Alternative 2 may have a minor (less than 3%) decrease in estimated fry rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in April (7-8%) in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Juvenile Rearing Habitat Analyses

Under the four phases of Alternative 2, mean juvenile rearing WUA decreases in all water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). There are no expected increases in estimated juvenile rearing habitat between the four phases of Alternative 2 and the No Action Alternative. The largest reduction in estimated juvenile rearing habitat is between Alternative 2 With TUCP Without VA and the No Action Alternative is a 1.5% decrease in above normal water year types. The median value of estimated juvenile rearing WUA under the four phases of Alternative 2 are similar to the No Action Alternative January through March and in May (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

There are some differences in juvenile rearing WUA on a monthly scale between the four phases of Alternative 2 and the No Action Alternative. In April, there is a 6% reduction in the median value of juvenile rearing WUA under Alternative 2 Without TUCP with Systemwide VA in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under all of the modeled alternatives are similar for January through March, but they are generally lower for April and May. For the January through March period, as described above for spring-run Chinook salmon fry rearing WUA, the third quartiles of the WUA distributions have high values and reduced variation. This occurs because, as described for the fry rearing WUA curves, the juvenile rearing WUA curves peak at the lowest flows encountered in the river and low flows are frequent during January through March in dry and critically dry years when Shasta Reservoir is operated to rebuild storage (Table O-182 through Table O-185).

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for spring-run Chinook salmon in the upper Sacramento River have a 1.3% to –2.7% difference between the months of January and May (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in the month of May under Alternative 2 Without TUCP without Delta VA and the greatest reduction in estimated habitat may occur in April under Alternative 2 Without TUCP with Systemwide VA in comparison to the No Action Alternative.

The results of the two spring-run Chinook salmon juvenile rearing habitat analyses suggest that the four phases of Alternative 2 may have a minor (less than 2%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in April (6%) in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. The four phases of Alternative 2 differ in how juvenile stranding of spring-fun fry varies with water year type (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Under Alternative 2 Without TUCP Without VA and Alternative 2 Without TUCP Delta VA, juvenile stranding steadily increases from critically dry to wet water years, while for the other two phases of Alternative 2, the rate of stranding falls from critically dry to dry or below normal water years before trending upward (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The four phases of

Alternative 2 show similar patterns of variation across the four principal months of spring-run fry rearing, with highest medians in November, lowest medians in December and January, and intermediate medians in February (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The means of spring-run Chinook salmon fry stranding under the four phases of Alternative 2 differ inconsistently from the means under the No Action Alternative (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The largest difference is a 10.4% reduction for below normal water years under Alternative 2 Without TUCP Systemwide VA and the largest increase is 10.1% for critically dry water years under Alternative 2 With TUCP Without VA. All four phases of Alternative 2 show reductions in stranding relative to the No Action Alternative in wet and above normal water years (ranging from 1.7% to 9.1% lower) and show a mix of increases and reductions for the drier water year types. Large (>5%) reductions outnumber large increases five to one.

Overall, reductions in fry standing are more frequent than increases for all four phases, relative to the No Action Alternative.

Survival and Travel Time: XT and Flow Survival Threshold Models

Differences in daily flows (Upper Sacramento River Daily Operations Model, USRDOM) under all four phases of Alternative 2 compared with the No Action Alternative may have effects on juvenile Chinook salmon's travel time and survival probabilities in the Upper Sacramento River. These possible differences were evaluated using several quantitative models. For a detailed description of how flows under Alternative 2 phases may impact juveniles and yearlings' travel time and survival probabilities in the Upper Sacramento River, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.1).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for juvenile growth, smoltification, and predation vulnerability during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 66 for Keswick Dam, Table 68 for RBDD, and Table 70 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating juveniles during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 74 for Keswick Dam, Table 76 for RBDD, and Table 78 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for yearling growth, smoltification, and predation vulnerability are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 82 for Keswick Dam during April through December, Table 84 for RBDD during April through December, and Table 98 for Hamilton City during October through December (migration only). Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating yearlings are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 88 for Keswick Dam during April through December, Table 90 for RBDD during April through December, and Table 106 for Hamilton City during October through December (migration only).

Results for the four analyses are summarized in Table O-40. Table O-40, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to one month-water year type combinations (0% to 2.5% of total combinations during the period) with favorable results depending on location (Table O-40). There were zero to three combinations (0% to 7.5%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 2 With TUCP Without VA, there would be no combinations with either favorable or unfavorable results at any location. For the 55.4°F to 68°F yearling optimum temperature range under Alternative 2 With TUCP Without VA, there would be zero to two combinations with favorable results (0% to 4.4%) with favorable results depending on location. There would be zero to three combinations (0% to 6.7%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating yearlings under Alternative 2 With TUCP Without VA, there would be no combinations with either favorable or unfavorable results at any location. These results indicate that there would be a mix of minor favorable and unfavorable water temperature-related conditions under Alternative 2 With TUCP Without VA related to optimum temperatures on juveniles and yearlings but no effect of Alternative 2 With TUCP Without VA on lethal temperatures.
- Under **Alternative 2 Without TUCP Without VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to two month-water year type combinations (0% to 6.7% of total combinations during the period) with favorable results depending on location (Table O-40). There were zero to three combinations (0% to 7.5%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 2 Without TUCP Without VA, there would be no combinations with either favorable or unfavorable results at any location. For the 55.4°F to 68°F yearling optimum temperature range under Alternative 2 Without TUCP Without VA, there would be zero to two combinations with favorable results (0% to 4.4%) with favorable results depending on location. There would be zero to five combinations (0% to 11.1%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating yearlings under Alternative 2 Without TUCP Without VA, there would be no combinations with either favorable or unfavorable results at any location. These results indicate that there would be a mix of minor favorable and unfavorable water temperature-related conditions under Alternative 2 Without TUCP Without VA related to optimum temperatures on juveniles and yearlings but no effect of Alternative 2 Without TUCP Without VA on lethal water temperatures.
- Under **Alternative 2 Without TUCP Delta VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were one to two month-water year type combinations (3.3% to 5.0% of total combinations during the period) with favorable results depending on location (Table O-40). There were one to three combinations (2.5% to 7.5%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 2 Without TUCP Delta VA, there would be no combinations

with either favorable or unfavorable results at any location. For the 55.4°F to 68°F yearling optimum temperature range under Alternative 2 Without TUCP Delta VA, there would be one to four combinations with favorable results (2.2% to 8.9%) with favorable results depending on location. There would be zero to three combinations (0% to 6.7%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating yearlings under Alternative 2 Without TUCP Delta VA, there would be no combinations with either favorable or unfavorable results at any location. These results indicate that there would be a mix of minor favorable and unfavorable water temperature-related conditions under Alternative 2 Without TUCP Delta VA related to optimum temperatures on juveniles and yearlings but no effect of Alternative 2 Without TUCP Delta VA on lethal water temperatures.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to one month-water year type combinations (0% to 3.3% of total combinations during the period) with favorable results depending on location (Table O-40). There were one to three combinations (3.3% to 7.5%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 2 Without TUCP Systemwide VAs, there would be no combinations with either favorable or unfavorable results at any location. For the 55.4°F to 68°F yearling optimum temperature range under Alternative 2 Without TUCP Systemwide VAs, there would be zero to two combinations with favorable results (0% to 4.4%) with favorable results depending on location. There would be zero to three combinations (0% to 6.7%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating yearlings under Alternative 2 Without TUCP Systemwide VAs, there would be no combinations with either favorable or unfavorable results at any location. These results indicate that there would be a mix of minor favorable and unfavorable water temperature-related conditions under Alternative 2 Without TUCP Systemwide VAs related to optimum temperatures on juveniles and yearlings but no effect of Alternative 2 Without TUCP Systemwide VAs on lethal temperatures.

Overall, the four phases of Alternative 2 would have similar water temperature-related effects to spring-run Chinook salmon juvenile and yearling rearing and outmigration in the Sacramento River (Table O-40). All four phases would have mostly small positive and negative effects related to the optimum temperature range for juvenile and yearling growth, smoltification, and predation vulnerability and no effects related to the UILT for juveniles and yearlings.

<u>Summary</u>

Alternative 2 relative to the No Action Alternative is largely expected to have negligible impacts on spring-run Chinook salmon fry and juvenile rearing habitat due to differences in flow. However, Alternative 2 relative to the No Action Alternative is expected to have an adverse impact on juvenile stranding in drier water year types. Mean annual survival and mean survival is increased and travel time decreased, which could have a beneficial impact on juvenile and yearling spring-run Chinook salmon. Alternative 2 relative to the No Action Alternative is expected to have an adverse water temperature-related impacts below Keswick Dam on juvenile growth, smoltification, and predation vulnerability, and a negligible impact at Red Bluff Diversion Dam and Hamilton City. Yearling growth, smoltification, and predation vulnerability

would be minorly adversely impacted below Keswick Dam and Red Bluff Diversion Dam under all phases, and minorly beneficially impacted below Keswick Dam and Hamilton City. Water temperatures above the incipient lethal limit for juveniles and yearlings are not expected to change in frequency under Alternative 2 relative to the No Action Alternative.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon enter the San Francisco Estuary from the Pacific Ocean to begin their upstream spawning migration in late January and early February (California Department of Fish and Game 1998). Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). While maturing, adults hold in deep pools with cold water. Documentation of holding locations in the Sacramento River was not identified.

Spring-run Chinook salmon adults enter the Sacramento River from March to September, primarily in May and June (Moyle 2002; Yoshiyama et al. 1998). In the upper Sacramento River, migration extends from mid-March through July with peak migration in late May and early June (California Department of Fish and Wildlife 1998).

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

<u>CalSim 3 Flows</u>

- **Alternative 2 With TUCP Without VA:** During the January through June/July period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 With TUCP Without VA at Sacramento River below Red Bluff Diversion Dam, Keswick Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative, except for an increase in January of critically dry water year types (up to 7% greater) and a decrease in May to July in critically dry water year types (up to 13% less at Keswick Dam) at all four locations. At Sacramento River below Keswick Dam, flows under Alternative 2 With TUCP Without VA would range from less than to greater than flows under the No Action Alternative, depending on month and water year type. Flows are generally greater than flows under the No Action Alternative in January and February and generally similar to or less than flows under the No Action Alternative in May through July, except lower in critically dry water year types. Flows at Hamilton City and Wilkins Slough under Alternative 2 With TUCP Without VA would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 2 With TUCP Without VA would be greater than 5,300 cfs at Wilkins Slough and greater than 7,500 cfs at Hamilton City (Table O-186, Table O-182, Table O-190, Table O-194).
- **Alternative 2 Without TUCP Without VA:** During the January through June/July period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Without VA at Sacramento River below Red Bluff Diversion Dam, Keswick Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative, except an increase in April (up to 21% in a critically dry water year type) and a decrease in May and June (up to 6% less in a critically dry water year type). At Sacramento River below Keswick Dam flows under Alternative 2 Without TUCP Without VA would range from less than to greater than

flows under the No Action Alternative, depending on month and water year type. Flows are generally greater than flows under the No Action Alternative January through April (up to 25% greater in April of a critically dry water year type) and generally similar to or less than flows under the No Action Alternative May and June (up to 10% lower in May of a critically dry water year type). Flows at Hamilton City and Wilkins Slough under Alternative 2 Without TUCP Without VA would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 2 Without TUCP Without VA would be greater than 5,300 cfs at Wilkins Slough and greater than 7,550 cfs at Hamilton City (Table O-187, Table O-183, Table O-191, Table O-195).

- **Alternative 2 Without TUCP Delta VA:** During the January through June/July period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Delta VA at Sacramento River below Red Bluff Diversion Dam, Keswick Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative, except an increase in April (up to 25% greater in a critically dry water year type) and a decrease in May and June (up to 6% less in dry and critically dry water year types). At Sacramento River below Keswick Dam flows under Alternative 2 Without TUCP Delta VA would range from less than to greater than flows under the No Action Alternative, depending on month and water year type. Flows are generally greater than flows under the No Action Alternative in January and February and in April (up to 30% greater in April of a critically dry water year type) and generally similar to or less that flows under the No Action Alternative in May and June (up to 10% less in May of a critically dry water year type). Flows at Hamilton City and Wilkins Slough under Alternative 2 Without TUCP Delta VA would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 2 Without TUCP Delta VA would be greater than 5,300 cfs at Wilkins Slough and greater than 7,550 cfs at Hamilton City (Table O-188, Table O-184, Table O-192, Table O-196).

- **Alternative 2 Without TUCP Systemwide VA:** During the January through June/July period of adult winter-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Systemwide VA at Sacramento River below Red Bluff Diversion, below Keswick Dam, Hamilton City and at Wilkins Slough would range from less than to greater than flows, depending on month and water year type. Flows are generally greater than flows under the No Action Alternative January through April (up to 28% greater in a critically dry water year type) and generally lower than flows under the No Action Alternative May through July (up to 7% lower in a critically dry water year type). At Hamilton City flows under Alternative 2 Without TUCP Systemwide VA would generally be similar to flows under the No Action Alternative except April in a critically dry year type (up to 29% greater) and June of most water year types (up to 8% less). Flows at Hamilton City and Wilkins Slough under Alternative 2 Without TUCP Systemwide VA would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 2 Without TUCP Systemwide VA would be greater than 5,100 cfs at Wilkins Slough and greater than 7,550 cfs at Hamilton City from January to July (Table O-189, Table O-185, Table O-193, Table O-197).

Overall, the four phases of Alternative 2 would have similar flows compared to the No Action Alternative. However, for all of the phases, flows are greater in January and February and decreased from May to July (up to 9%) during critically dry water years. Flows at Hamilton City and Wilkins Slough are sufficient to allow passage and holding for all four phases during all water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during March through September are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 40 for Keswick Dam, Table 42 for RBDD, and Table 44 for Hamilton City.

Results for the analysis are summarized in Table O-41. Table O-41, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under all four phases of Alternative 2, there were zero to one month-water year type combinations (0% to 2.9% of total combinations during the period) with favorable results and zero to two combinations (0% to 5.7%) with unfavorable results, depending on location (Table O-41). These results suggest that there would be mostly negligible water temperature-related effects of all four phases of Alternative 2 on spring-run Chinook salmon migration and holding in the Sacramento River.

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts, depending on location and month, on upstream migrating and holding adult spring-run Chinook salmon due to differences in flow. Average monthly flows at Hamilton City and Wilkins Slough are high enough to allow upstream passage. Alternative 2 relative to the No Action Alternative is expected to have negligible water temperature-related impacts on upstream migrating and holding adult spring-run Chinook salmon.

O.5.9.2 Clear Creek

Spawning and Egg Incubation

Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities to promote higher oxygen levels. Spawning in Clear Creek normally occurs between mid-August and early October, peaking in September (Moyle 2002).

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under the four phases of Alternative 2, mean spawning WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean spawning WUA under the four phases of Alternative 2 in comparison to the No Action Alternative. The largest reduction in estimated

spawning habitat is an 18.7% decrease in critically dry water year types under Alternative 2 Without TUCP with Systemwide VA. On average across all water year types, there is a 10.8-13.6% reduction in estimated spawning habitat under the four phases of Alternative 2.

The mean values of spawning WUA by month are lower under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). October is expected to have the highest spawning WUA values under the four phases of Alternative 2.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for spring-run in Clear Creek may be a limiting factor under all of the modeled alternatives and that spawning habitat may decrease 9.5-11.1% in September and October for the four phases of Alternative 2 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The two spawning habitat analyses suggest that the four phases of Alternative 2 may have an adverse impact (up to 18.7% decrease) in spring-run Chinook salmon spawning habitat in Clear Creek across water year types when compared to the No Action Alternative, and that spawning habitat may be a limiting factor for spring-run Chinook salmon in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 52 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 58 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during September through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 6 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-42. Table O-42, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results below Whiskeytown Dam (Table O-42). For the 59.9°F pathogen virulence threshold, there were zero combinations (0%) with favorable and unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero (0%) combinations with favorable and unfavorable results below Whiskeytown Dam. These results suggest that there would be no effect of Alternative 2 With TUCP Without VA on spring-run Chinook salmon spawning in Clear Creek.

- Results for **Alternative 2 Without TUCP Without VA** were identical to those for Alternative 2 With TUCP Without VA (Table O-42).
- Results for **Alternative 2 Without TUCP Delta VA** were identical to those for Alternative 2 With TUCP Without VA (Table O-42).
- Results for **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-42).

Overall, the four phases of Alternative 2 would have no effect on water temperature conditions for spring-run Chinook salmon spawning in Clear Creek (Table O-42).

Summary

Alternative 2 relative to the No Action Alternative is expected to include a decrease in flows and have moderate to adverse impacts on spawning habitat area that is anticipated to have adverse impacts on spawning spring-run Chinook salmon, although changes in flows did not cause water temperature-related effects.

Juvenile–Yearling Rearing and Emigration

While the majority of juvenile spring-run Chinook salmon outmigrate as fry, a proportion rears in Clear Creek through the spring and summer and emigrates as subyearlings with the first rainstorms in the fall or winter following their birth (NMFS 2014a). Spring-run Chinook salmon outmigration from Clear Creek occurs during late October through late April with peak emigration of juveniles occurring in November, and few fish exiting through the end of May.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under the four phases of Alternative 2, mean fry rearing WUA increases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The greatest increase in estimated fry rearing habitat is a 7.8% increase in dry water year types under all four phases of Alternative 2. There are no anticipated reductions in mean fry rearing WUA under the four phases of Alternative 2 in comparison to the No Action Alternative.

The mean values of fry rearing WUA by month are generally higher under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the five fry rearing months, January and February are expected to have the highest fry rearing WUA values under the four phases of Alternative 2.

The results of the spring-run Chinook salmon fry rearing habitat analysis suggest that the four phases of Alternative 2 may have a minor (5.8-7.8%) increase in estimated spring-run Chinook salmon fry rearing habitat across all water year types in comparison to the No Action Alternative in Clear Creek.

Juvenile Rearing Habitat Analyses

Under the four phases of Alternative 2, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under

the four phases of Alternative 2 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 2 and the No Action Alternative is a 6.5% decrease in critically dry water year types. On average across all water year types, there is a 5.1-5.3% reduction in estimated juvenile rearing habitat under the four phases of Alternative 2.

The mean values of juvenile rearing WUA by month are lower June through August and higher in April and May under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the five months, May and June are expected to have the highest juvenile rearing WUA values.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for spring-run in Clear Creek may decrease 12-15 during the summer months (June through August) but may increase 4.2-12.6% in the spring months April and May under the four phases of Alternative 2 compared to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest decrease in estimated juvenile rearing habitat may occur in June and the greatest increase in estimated juvenile rearing habitat may occur in May.

The results of the two spring-run Chinook salmon juvenile rearing habitat analyses suggest that the four phases of Alternative 2 may have a minor adverse effect, as rearing habitat may decrease up to 5.3% across all water year types in comparison to the No Action Alternative, and that there may be increases to habitat in the spring and reductions in habitat in the summer in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for juvenile growth, smoltification, and predation vulnerability during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 72 below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating juveniles during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 80 below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for yearling growth, smoltification, and predation vulnerability are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 86 below Whiskeytown Dam April through December. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating yearlings are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 92 below Whiskeytown Dam for April through December.

Results for the four analyses are summarized in Table O-43. Table O-43, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- For the 55.4°F to 68°F juvenile optimum temperature range under **Alternative 2 With TUCP Without VA**, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-43). For the 75.2°F UILT for rearing and migrating juveniles, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam. For the 55.4°F to 68°F yearling optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam. For the 75.2°F UILT for rearing and migrating yearlings, there were no combinations (0%) with favorable results and two combinations (4.4%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on spring-run Chinook salmon juvenile and yearling rearing and emigration in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA** were identical to those for Alternative 2 With TUCP Without VA.
- Results for **Alternative 2 Without TUCP Delta VA** were identical to those for Alternative 2 Without TUCP With VA (Table O-43).
- Results for **Alternative 2 Without TUCP Systemwide VA** were identical to those for Alternative 2 Without TUCP With VA (Table O-43).

Overall, all 4 phases of Alternative 2 would have similar negligible effects on water temperature conditions for spring-run Chinook salmon juvenile and yearling rearing and emigration in Clear Creek (Table O-43).

Summary

Alternative 2 relative to the No Action Alternative is largely expected to have minor impacts on spring-run Chinook salmon fry and juvenile rearing habitat due to differences in flow. Fry rearing habitat is expected to increase, while juvenile rearing habitat may decrease up to 5.2% under Alternative 2 compared to the No Action Alternative. Increases in habitat in the spring and reductions in the summer are expected. Alternative 2 relative to the No Action Alternative is expected to be negligible water-temperature related impacts on juvenile and yearling rearing and emigration. There are some adverse water temperature impacts related to the critical upper temperature limit for yearlings under all 4 phases of Alternative 2.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon migrate into Clear Creek from April to August, and peak passage occurs in May and June (Clear Creek Technical Team 2018; Giovannetti et al 2013). Adults distribute throughout Clear Creek and hold in deep pools throughout the summer from Whiskeytown Dam (river mile 18.3) as far downstream as river mile 4.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

CalSim 3 Flows

- **Alternative 2 With TUCP Without VA**
    - During the April through August period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 With TUCP Without VA at Clear Creek below Whiskeytown Dam would generally be higher or lower compared to the No Action Alternative. Flows are much higher from March to May, ranging from an increase of 14% to 54% in May of a critically dry year. From June to August flows are much lower, ranging from -3% in July of a critically dry year to -36% in June of a critically dry year. Flows are greater than flows under the No Action Alternative March through May and less than flows under the No Action Alternative in June through August in almost all water year types. The average monthly flows across all water year types under Alternative 2 With TUCP Without VA range from 119 cfs in August to 261 cfs in May (Table O-218).
    - Flows during the spring-run immigration and holding will be less than the No Action Alternative during the main passage and holding months. This reduction could have a negative effect on adult spring-run Chinook salmon.
- **Alternative 2 Without TUCP Without VA**
    - During the April through August period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Without VA at Clear Creek below Whiskeytown Dam would generally be higher or lower compared to the No Action Alternative. Flows are much higher from March to May, ranging from 14% to 54% in May of a critically dry year. From June to August flows are much lower, ranging from -3% in July of a critically dry year to -33% in June of a critically dry year. Flows are greater than flows under the No Action Alternative March through May and less than flows under the No Action Alternative in June through August in almost all water year types. The average monthly flows across all water year types under Alternative 2 Without TUCP Without VA range from 113 cfs in July to 261 cfs in May (Table O-219).
    - Flows during the spring-run Chinook salmon immigration and holding will be less than the No Action Alternative during the main passage and holding months. This reduction could have a negative effect on adult Spring-run Chinook salmon.
- **Alternative 2 Without TUCP Delta VA**
    - During the April through August period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Delta VA at Clear Creek below Whiskeytown Dam would be higher or lower compared to the No Action Alternative. Flows are much higher from March to May, ranging from 14% to 54% in May of a critically dry year. From June to August flows are much lower, ranging from -7% in August of a critically dry year

to -33% in June of a critically dry year. Flows are greater than flows under the No Action Alternative March through May and less than flows under the No Action Alternative in June through August in almost all water year types. The average monthly flows across all water year types under Alternative 2 Without TUCP Delta VA range from a low of 112 cfs in July to a high of 261 cfs in May (Table O-220).

- Flows during the spring-run Chinook salmon immigration and holding will be less than the No Action Alternative during the main passage and holding months. This reduction could have a negative effect on adult spring-run Chinook salmon.

- **Alternative 2 Without TUCP Systemwide VA**
    - During the April through August period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 2 Without TUCP Systemwide VA at Clear Creek below Whiskeytown Dam would be higher or lower compared to the No Action Alternative. Flows are much higher from March to May, ranging from 14% to 54% in May of a critically dry year. From June to August flows are much lower, ranging from -7% in August of a critically dry year to -33% in June of a critically dry year. Flows are greater than flows under the No Action Alternative March through May and less than flows under the No Action Alternative in June through August in almost all water year types. The average monthly flows across all water year types under Alternative 2 Without TUCP Systemwide VA range from a low of 112 cfs in July to a high of 261 cfs in May (Table O-221).
    - Flows during the spring-run Chinook salmon immigration and holding will be less than the No Action Alternative during the main passage and holding months. This reduction could have a negative effect on adult spring-run Chinook salmon.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during March through September are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 46 below Whiskeytown Dam.

Results for the analysis are summarized in Table O-44. Table O-44, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP With VA** for the 37.9°F to 68°F successful adult migration range, there were zero month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results below Whiskeytown Dam (Table O-44). These results suggest that there would be no effect of Alternative 2 With TUCP with VA on spring-run Chinook salmon adult upstream migration and holding in Clear Creek.

- Results for **Alternative 2 Without TUCP With VA**, **Alternative 2 Without TUCP Delta VA** and **Alternative 2 With TUCP With VA** were identical to those for Alternative 2 With TUCP With VA (Table O-44).

Overall, all 4 phases of Alternative 2 would have no effect on water temperature conditions for spring-run Chinook salmon adult upstream migration and holding in Clear Creek (Table O-44).

Summary

Alternative 2 relative to the No Action Alternative is expected to have an adverse impact on adult spring-run Chinook salmon migration and holding habitat due to differences in flow. Alternative 2 relative to the No Action Alternative could have no water temperature-related impacts on adult migration and holding.

O.5.9.3 Bay-Delta

Juvenile–Yearling Rearing and Emigration

Juvenile spring-run Chinook salmon show two distinct out-migration patterns in the Central Valley: out-migrating to the Delta and ocean during their first year of life as YOY or holding over in their natal streams and out-migrating the following fall/winter as yearlings. YOY spring-run Chinook salmon presence in the Delta peaks during April and May, as suggested by the recoveries of Chinook salmon in the CVP and SWP salvage operations and the Chipps Island trawls of a size consistent with the predicted size of spring-run fish at that time of year.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Zone of Influence

Differences in hydrology under the four phases of Alternative 2 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions.

With incremental decreases in OMR under all four phases of Alternative 2 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under the four phases of Alternative 2 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2, *Zone of Influence*).

Flow into Junctions

Alternative 2 relative with the No Action Alternative is expected to have effects on the flow into the Head of Old River and CVP junctions due to differences in flow routing. For a detailed description of how flows under the four phases of Alternative 2 may impact the flow at Head of Old River and CVP, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2, *Flow into Junctions*).

Under all four phases of Alternative 2 and for most OMR bins except -3,500, the predicted proportion of flow entering the CVP is less than the No Action Alternative, although the predicted difference was negligible (up to ± 0.0467 for Alternative 2 Without TUCP Delta VA). Exceptions include the -2,000 OMR bin, with slightly greater change in predicted proportion of flow into CVP for Alternative 2 With TUCP Without VA (-0.069) or Alternative 2 Without TUCP Without VA (-0.0631) indicating that slightly less flow will be routed into CVP under these conditions compared to the No Action Alternative.

Under all four phases of Alternative 2 and for all OMR bins, the predicted differences in proportion of flow entering the HOR compared to the No Action Alternative are negligible (either positive or negative, but always lower than ± 0.008),

Summary

Alternative 2 With TUCP Without VA and without TUCP Without VA are expected to have slightly less flow into CVP at OMR -2,000 and Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA are expected to have negligible impacts on flow into CVP. Impacts of pumping under all four phases of Alternative 2 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Spring-run Chinook Salmon from Entrainment

Salvage Density and Negative Binomial

- **Alternative 2 With TUCP Without VAs**
    - Predictions from the salvage density and the negative binomial model for LAD spring-run Chinook salmon include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP and Table O-242 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between the four phases of Alternative 2 and the No Action Alternative.
    - Predicted average monthly loss of LAD spring-run Chinook salmon at SWP Banks Pumping Plant for all the months January through June, of all water year types Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative, up to 116% greater in above normal water year types (Table O-45). Predicted average monthly loss of LAD spring-run Chinook salmon under Alternative 2 at CVP Jones Pumping Plant, for all the months December through June of all water year types, was greater or equal to predicted average monthly loss under the No Action Alternative, up to a maximum of 4% greater in below normal water year types. The predicted loss of LAD spring-run Chinook salmon at Jones for Alternative 2 With TUCP Without VAs compared to the No Action Alternative was lower for the dry water year types, with 1% reduction in predicted loss (Table O-46). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of LAD spring-run Chinook salmon at the Delta fish collection facilities for the months of March through June under Alternative 2 With TUCP Without VAs was greater than predicted loss under the No Action Alternative for all water year types, with loss up to 95% greater for above normal water year types (Table O-47). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

- **Alternative 2 Without TUCP Without VAs**

  - Predictions from the salvage density and negative binomial model for genetic and LAD spring-run Chinook salmon include mean monthly total exports. Predictions from the negative binomial loss model for LAD spring-run Chinook salmon include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP and Table O-243 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between the four phases of Alternative 2 and the No Action Alternative.

  - Predicted average monthly loss of LAD spring-run Chinook salmon at SWP Banks Pumping Plant for all the months January through June, of all water year types, under Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative, with loss up to 116% greater in above normal water year types (Table O-45). Predicted average monthly loss of LAD spring-run Chinook salmon at CVP Jones Pumping Plant for all the months December through June under Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for all water year types except for the dry water year types, which had a reduction of 1% in predicted loss. For all other water year types, the predicted loss of LAD spring-run Chinook salmon increased under Alternative 2 Without TUCP Without VAs as compared to the No Action Alternative, with loss up to 5% greater in critically dry water year types (Table O-46). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

  - Predicted average monthly salvage of LAD spring-run Chinook salmon at the Delta fish collection facilities for the months of March through June under Alternative 2 Without TUCP Without VAs was greater than predicted loss under the No Action Alternative for all water year types, with loss up to 94% greater for above normal water year types. (Table O-47). For detailed information on average monthly salvage by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- **Alternative 2 Without TUCP With Delta VAs**

  - Predictions from the salvage density and the negative binomial model for LAD spring-run Chinook salmon include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP and Table O-244 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer

to the tables for differences between the four phases of Alternative 2 and the No Action Alternative.

- Predicted average monthly loss of LAD spring-run Chinook salmon at SWP Banks Pumping Plant, for all the months January through June of all water year types, under Alternative 2 Without TUCP with Delta VAs was greater than predicted average monthly loss under the No Action Alternative, with loss up to 69% greater in above normal water year types (Table O-45). Predicted average monthly loss of LAD spring-run Chinook salmon at CVP Jones Pumping Plant for all the months December through June for Alternative 2 Without TUCP with Delta VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types except for the critically dry water year types, which had an increase of 3% in predicted loss. For all other water year types, the predicted loss of LAD spring-run Chinook salmon decreased under Alternative 2 Without TUCP with Delta VAs as compared to the No Action Alternative, with up to a 13% reduction in predicted loss for the dry water year types (Table O-46). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of LAD spring-run Chinook salmon at the Delta fish collection facilities for the months of March through June under Alternative 2 Without TUCP with Delta VAs was greater than predicted loss under the No Action Alternative for all water year types, with up to 25% greater for below normal water year types. (Table O-47). For detailed information on average monthly salvage by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- **Alternative 2 Without TUCP Systemwide VAs**

  - Predictions from the salvage density and the negative binomial model for LAD spring-run Chinook salmon include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP and Table O-245 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between the four phases of Alternative 2 and the No Action Alternative.

  - Predicted average monthly loss of LAD spring-run Chinook salmon at SWP Banks Pumping Plant, for all the months January through June of all water year types, under Alternative 2 Without TUCP Systemwide VAs was greater than predicted average monthly loss under the No Action Alternative, with loss up to 67% greater in above normal water year types (Table O-45). Predicted average monthly loss of LAD spring-run Chinook salmon at CVP Jones Pumping Plant for all the months December through June for Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types except for the critically dry water year types, which had an increase of 2% in predicted loss. For all other water year types, the predicted loss of LAD spring-run Chinook salmon decreased under Alternative 2 Without TUCP Systemwide VAs as compared to the No Action

Alternative, with up to a 13% reduction in predicted loss for the dry water year types (Table O-46). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of LAD spring-run Chinook salmon at the Delta fish collection facilities for the months of March through June under Alternative 2 Without TUCP Systemwide VAs was greater than predicted loss under the No Action Alternative for all water year types, with up to 26% greater for below normal water year types (Table O-47). For detailed information on average monthly salvage by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Summary

Alternative 2 relative to the No Action Alternative is expected to have effects on entrainment of juvenile spring-run Chinook salmon in the Delta are generally the same due to similar flows. Alternative 2 relative to the No Action Alternative is expected to have an increase in average monthly loss at SWP and a decrease of loss at CVP. Salvage is expected to increase under Alternative 2 relative to the No Action Alternative regardless of water year type. Alternative 2 relative to the No Action Alternative is expected to have an adverse impact at SWP due to differences in flow.

Potential Changes to Routing of Spring-run Chinook Salmon

ECO-PTM

Alternative 2 relative to the No Action Alternative is expected to have effects on juvenile Chinook salmon's routing to Interior Delta via Georgiana Slough in the Delta. For a detailed description of how flows under the phases of Alternative 2 may impact spring-run Chinook salmon routing, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2).

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under Alternative 2 ranged from less than the No Action Alternative (up to 7% less under -5,000 cfs under Alternative 2 Without TUCP Without VA and Alternative 2 With TUCP Without VA) to greater than the No Action Alternative (up to 9% greater under -3,500 cfs under Alternative 2 Without TUCP Delta VA) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in the attachment. The decrease in routing to the Interior Delta could have a beneficial effect on outmigrating juveniles while the increase in routing could have an adverse impact on outmigrating juveniles.

Summary

The quantitative model suggests that depending on considered variables, flows under the four phases of Alternative 2 compared with the No Action Alternative may have minor adverse or minor beneficial impacts for outmigrating juvenile Chinook salmon in the winter and spring, dependent on OMR grouping.

Potential Changes to Through Delta Survival of Spring-run Chinook Salmon

ECO-PTM

Differences in flows under all four phases of Alternative 2 compared with the No Action Alternative may have effects on juvenile Chinook salmon's through-Delta survival. For a detailed description of how flows under the phases of Alternative 2 may impact spring-run Chinook salmon through-Delta survival, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2).

Mean through-Delta percent survival December through March under the four phases of Alternative 2 were not as consistent among phases of Alternative 2 as ECO-PTM routing results were. Mean through-Delta survival under the phases with no VA, Alternative 2 Without TUCP Without VA and with TUCP Without VA, ranged from less than the No Action Alternative (up to 4% less under -2,000 cfs) to greater than the No Action Alternative (up to 4% greater under -5,000 cfs) (Attachment I.7, *ECO-PTM*). Mean through-Delta survival under the phases with VA, Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA, ranged from less than the No Action Alternative (up to 5% less under -3,500 cfs) to greater than the No Action Alternative (up to 18% greater under -2,000 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in the *attachment*. The increase in survival under some OMR conditions under phases of Alternative 2 with VA could have a large beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have an adverse impact on outmigrating juveniles.

Delta Passage Model

- Under **Alternative 2 With TUCP Without VA**, in all except critically dry water year types, predicted mean survival of spring-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted survival to Chipps Island in all water year types is less than or equal to ± 0.002. There is not a substantial difference in predicted proportion of spring-run Chinook salmon surviving to Chipps Island between Under Alternative 2 With TUCP Without VA and the No Action Alternative.
- Under **Alternative 2 Without TUCP Without VA**, in all except critically dry water year types, predicted mean survival of spring-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative. The change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.007.
- Under **Alternative 2 Without TUCP Delta VA**, in all except critically dry and dry water year types, predicted mean survival of spring-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative. The change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.006.
- Under **Alternative 2 Without TUCP Systemwide VA**, in all except wet water year types, predicted mean survival of spring-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative. The change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.009.

Summary

Alternative 2 relative to the No Action Alternative is expected to have a possible adverse or beneficial impact on survival of outmigrating juvenile spring-run Chinook salmon depending on OMR grouping due to differences in flow.

O.5.10 California Central Valley Steelhead DPS

O.5.10.1 Sacramento River

Spawning and Egg Incubation

Steelhead primarily use the Sacramento River as a migratory corridor for reaching other tributaries to spawn. Data on steelhead spawning in the mainstem Sacramento River is limited and likely restricted to the area upstream of Red Bluff (National Marine Fisheries Service 2009a). No steelhead specific spawner surveys occur in the upper Sacramento River. Data from recent surveys for the four runs of Chinook salmon have found carcasses of *O. mykiss* but the majority are thought to be resident trout adults (Killam 2022). Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In the Sacramento River, estimated incubation timing based on spawning is December through June.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under the four phases of Alternative 2, differences in mean spawning WUA vary depending on water year type but are below a 1.5% difference across all water year types and phases when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between the four phases of Alternative 2 and the No Action Alternative is a 1.25% increase in above normal water years under Alternative 2 Without TUCP Without VA. The largest reduction in estimated spawning habitat is a -1.0% decrease in below normal water year types under Alternative 2 Without TUCP Systemwide VA.

The monthly median values of spawning WUA under the four phases of Alternative 2 are similar to the No Action Alternative in May, June, and August but are slightly higher in July (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are relatively similar in January through March. In April, the median values of spawning WUA are higher across all alternatives when compared to the other spawning months. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently lowest in April when compared to other spawning months (Table O-182 through Table O-185). This results in lower spawning WUA results because the steelhead spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 4,000 to 7,000 cfs).

The results of suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for steelhead in the upper Sacramento River may increase in April under all alternatives compared to the other spawning months (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

Lack of consistent spawner estimates for steelhead prevented Reclamation staff from calculating spawner limitation ratios for this species.

The results of the two spawning habitat analyses based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 are expected to have a negligible (less than 2%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. Out of the four months of steelhead spawning, April has the highest estimated spawning WUA across all alternatives.

Redd Dewatering Analysis

All phases of Alternative 2 show a consistent and large reduction in mean potential from wetter to drier water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation reflects flow conditions for the winter and early spring months, when steelhead spawning and incubation occurs. During wet winters and springs, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. Most differences in mean redd dewatering potential between Alternative 2 and the No Action Alternative are reductions, ranging from 0.2% in wet water years under Alternative 2 With TUCP Without VA and Alternative 2 Without TUCP With Delta VA to 30.3% for Alternative 2 Without TUCP With Delta VA in critically dry water years. A 7.7% increase for Alternative 2 Without TUCP With Systemwide VA is the only increase greater than 1%. Note that, on an absolute scale, the largest differences for all water year types between the Alternative 2 scenarios and the No Action Alternative is a reduction of 2.1% for Alternative 2 Without TUCP With Systemwide VA in above normal years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that redd dewatering potential under the four phases of Alternative 2 would mostly be lower than under the No Action Alternative, but the reductions on an absolute difference scale are small.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis* Table 134 for Keswick Dam and Table 136 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 140 for Keswick Dam and Table 142 for RBDD. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 170 for Keswick Dam and Table 172 for RBDD.

Results for the three analyses are summarized in Table O-48. Table O-48, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 45.5°F to 55°F successful spawning range analysis, there were five and one month-water year type combinations (16.7% and 3.3% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-48). There were one and zero combinations (3.3% and 0%, respectively) with unfavorable results at both Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were zero and five combinations (0% and 16.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. For the 45°F to 52°F range for optimal egg incubation, there were eight and zero combinations (22.9% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were four and zero combinations (11.4% and 0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be frequent positive water temperature-related effects and some negative effects of Alternative 2 With TUCP Without VA on steelhead spawning and egg incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 45.5°F to 55°F successful spawning range analysis, there were six and zero month-water year type combinations (20.0% and 0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-48). There were one and zero combinations (3.3% and 0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were zero and five combinations (0% and 16.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. For the 45°F to 52°F range for optimal egg incubation, there were eight and zero combinations (22.9% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were five and zero combinations (14.3% and 0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be frequent positive water temperature-related effects and some negative effects of Alternative 2 Without TUCP Without VA on steelhead spawning and egg incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Delta VA** for the 45.5°F to 55°F successful spawning range analysis, there were five and one month-water year type combinations (16.7% and 3.3% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-48). There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. For the 59.9°F pathogen virulence threshold, there were zero and five combinations (0% and 16.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. For the 45°F to 52°F range for optimal egg incubation, there were seven and zero combinations (20.0% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were three and zero combinations (8.6% and 0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be frequent positive water temperature-related effects and some negative effects of Alternative 2 Without TUCP Delta VA on steelhead spawning and egg incubation in the Sacramento River.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 45.5°F to 55°F successful spawning range analysis, there were five and one month-water year type combinations (16.7% and 3.3% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-48). There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. For the 59.9°F pathogen virulence threshold, there were zero and five combinations (0% and 16.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. For the 45°F to 52°F range for optimal egg incubation, there were seven and zero combinations (20.0% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were three and zero combinations (8.6% and 0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be frequent positive effects and some negative effects of Alternative 2 Without TUCP Systemwide VAs on steelhead spawning and egg incubation in the Sacramento River.

Overall, the four phases of Alternative 2 would have positive and negative water temperature-related effects to steelhead spawning and egg incubation in the Sacramento River (Table O-48).

Sacramento River Pulse Flows

To increase outmigration survival of Chinook salmon, Reclamation would release up to 150 TAF in pulse flow(s) each water year, typically in the spring, to benefit Chinook salmon in the Sacramento River watershed when the pulse does not interfere with the ability to meet temperature objectives or other anticipated operations of the reservoir. Reclamation will schedule this pulse after coordination through the Sacramento River Group and Shasta Operations Team and may include coordinating timing with natural flow events, potential storage management operations and/or pulse flows in tributaries. There may be unintentional adverse impacts of spring pulse flows on steelhead spawning behavior and redd dewatering from sudden drops in flow. Redd surveys are occurring during the pulse flow period and redd dewatering has not been observed.

Summary

There are expected minor adverse and beneficial impacts of seasonal operations on steelhead spawning and egg incubation based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under the four phases of Alternative 2, changes in flows are expected to have a minor increase and/or decrease on spawning habitat area and redd dewatering potential would generally be smaller. There may be adverse impacts to spawning behavior from spring pulse flows. There may be redd dewatering following spring pulse flow events, though this has not been observed during redd surveys. There would be similar beneficial and adverse water temperature-related effects of the four phases of Alternative 2 on steelhead spawning and egg incubation.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in the Sacramento River. The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station at Knight's Landing indicate outmigration into the Delta, with median passage starting in January and ending in May from 2006-2024 (Columbia Basin Research, University of Washington 2024).

Potential Changes to Steelhead from Seasonal Operations

Fry Rearing Habitat Analysis

Under the four phases of Alternative 2, mean fry rearing WUA increases in critically dry water year types and reductions in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). WUA curves were not developed for steelhead, so the late fall-run Chinook salmon curves were used to quantify steelhead habitat. The largest increase in estimated fry rearing habitat is under Alternative 2 With TUCP Without VA and the No Action Alternative, with a 5.8% increase in critically dry water year types. The largest reduction in estimated fry rearing habitat is under Alternative 2 Without TUCP with Systemwide VA, with a 1.1% decrease in below normal water year types.

There are some differences in fry rearing WUA on a monthly scale between the four phases of Alternative 2 and the No Action Alternative. In April, there is a 11% reduction in the median value of estimated fry rearing WUA under Alternative 2 Without TUCP with Systemwide VA and an 8% reduction under Alternative 2 Without TUCP with Delta VA in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). In September, there is a 6-7% reduction in the median value of estimated fry rearing WUA under Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP with Systemwide VA. In October, there is a 5% reduction in Alternative 2 Without TUCP with Delta VA. The four phases of Alternative 2 and the No Action Alternative are similar during the other fry rearing months. The estimated fry rearing WUA values under the modeled alternatives are highly variable across the months, April through October, but are generally highest in April and October. WUA values of the fry rearing WUA curve are lowest in the range of approximately 7,000 cfs to 13,000 cfs in Segment 5 and flows in this range are more frequent during May through August (Table O-182 through Table O-185).

The results of the steelhead fry rearing habitat analysis based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 compared to the No Action Alternative are expected to have a minor increase (up to 5.8%) and a minor decrease (less than 1.5%) in estimated fry rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in April (8-11%) in the mainstem upper Sacramento River.

Juvenile Rearing Habitat Analyses

Under the four phases of Alternative 2, mean juvenile rearing WUA decreases compared to the No Action Alternative across all water year types (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The upper and lower limits of the range in WUA values are determined by the ranges of the juvenile rearing WUA curves for late fall-run Chinook salmon since there

were no reliable WUA curves for steelhead. The analysis includes all months because steelhead juveniles may reside in freshwater for a year or more before emigrating to the ocean. There are no expected increases in estimated juvenile rearing habitat between the four phases of Alternative 2 and the No Action Alternative. The largest reduction in estimated juvenile rearing habitat is under Alternative 2 Without TUCP with Delta VA and the No Action Alternative, with a 1.4% decrease in above normal water year types.

The monthly median values of juvenile rearing WUA under the four phases of Alternative 2 are similar (less than 5% difference) to the No Action Alternative throughout the year (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under the modeled alternatives are similar December through March, and gradually decrease until the lowest estimated values in July. As discussed previously for spring-run rearing WUA and steelhead spawning WUA, the high WUA values with low variability in the third quartile for December through March result from the peaking of the WUA curve at the lowest flows and frequent low Keswick Dam flow releases during these months to build Shasta Reservoir storage (Table O-182 through Table O-185). The wide range of values in the first quartile of these months reflects the high frequency and variability of higher flows in these wet months. The low juvenile rearing WUA values June through August result from releases in the summer months above 10,000 cfs and estimated peak juvenile rearing at flows below 5,000 cfs.

The results of suitable habitat analysis using the SIT LCM habitat models suggest that juvenile rearing instream habitat for steelhead in the upper Sacramento River may have a 6.5% to -2.7% difference from January through December (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in June under Alternative 2 Without TUCP with Systemwide VA and the greatest reduction in estimated habitat may occur in April under Alternative 2 Without TUCP With Systemwide VA in comparison to the No Action Alternative.

The results of the two steelhead juvenile rearing habitat analyses suggest that the four phases of Alternative 2 in comparison to the No Action Alternative may have a minor (less than 2%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and the greatest increase in estimated habitat may occur in June (6.7%) in the mainstem upper Sacramento River.

<u>Fry Stranding Analysis</u>

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. The four phases of Alternative 2 show a similar pattern of variation in how juvenile stranding of steelhead fry varies with water year type (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). All four phases have the highest mean steelhead fry stranding in wet water years and relatively small differences among the other four water year types. Steelhead fry rearing occurs primarily during late winter and spring. All four phases of Alternative 2 show the highest stranding in February, with the median levels trending down over the next three months (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher mean stranding levels for steelhead fry during February and wet water year types likely results from periodic storms and high runoff that produce increased variability of flow. Differences in juvenile stranding of steelhead fry between the four phases of Alternative 2 and the No Action Alternative vary greatly, but except for

critically dry water years they all constitute reductions in stranding (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The largest reductions occur under Alternative 2 Without TUCP Systemwide VA, including 30.0% lower in below normal water year types and 19.8% lower in above normal water years. Reductions are large in dry water years under all four phases of Alternative 2, ranging from 9.6% lower under Alternative 2 Without TUCP Systemwide VA to 19.7% lower under Alternative 2 With TUCP Without VA. The only increases in mean stranding are 8.0% and 8.8% for Alternative 2 Without TUCP Delta VA and Alternative 2 Without TUCP Systemwide VA, respectively, in critically dry water years.

Overall, steelhead juvenile stranding for fry is lower under the four phases of Alternative 2 than under the No Action Alternative, but the magnitude of the differences varies greatly. Moderate increases in stranding occur in critically dry years for two phases of Alternative 2.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperature range year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 182 for Keswick Dam and Table 184 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 188 for Keswick Dam, Table 190 for Red Bluff Diversion Dam, and Table 192 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 55°F upper limit of successful smoltification during January through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 196 for Keswick Dam, Table 198 for Red Bluff Diversion Dam, and Table 200 for Hamilton City.

Results for the three analyses are summarized in Table O-49. Table O-49, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 66.2°F upper limit of optimum temperature range, there were zero month-water year type combinations (0%) with favorable or unfavorable results at Keswick Dam and RBDD (Table O-49). For the 59.9°F juvenile pathogen virulence threshold, there were zero to 14 combinations (0% and 23.3%, respectively) with favorable results depending on location. There were zero to one combination (0% to 1.7%) with unfavorable results depending on location. For the 55°F upper limit of successful smoltification, there were zero to five combinations (0% to 20.0%) with favorable results depending on location. There were zero to one combinations (0% to 4.0%) with unfavorable results depending on location. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 2 With TUCP Without VA on steelhead juvenile rearing and emigration.
- Under **Alternative 2 Without TUCP Without VA** for the 66.2°F upper limit of optimum temperature range, there were zero and one month-water year type combinations (0% and 1.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively

(Table O-49). For the 59.9°F juvenile pathogen virulence threshold, there was one to 15 combinations (1.7% to 25.0%) with favorable results depending on location. There were no combinations (0%)with unfavorable results at any of the locations. For the 55°F upper limit of successful smoltification, there were 0 to 5 combinations (0% to 20.0%) with favorable results depending on location. There were zero to one combinations (0% to 4.0%) with unfavorable results depending on location. These results suggest that there would be positive effects and negligible negative effects of Alternative 2 Without TUCP Without VA on steelhead juvenile rearing and emigration.

- Under **Alternative 2 Without TUCP Delta VA** for the 66.2°F upper limit of optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable or unfavorable results at both Keswick Dam and RBDD (Table O-49). For the 59.9°F juvenile pathogen virulence threshold, there were zero to 11 combinations (0% to 18.3%) with favorable results depending on location. There were zero combinations (0%) with unfavorable results at any location. For the 55°F upper limit of successful smoltification, there were zero to five combinations (0% to 20.0%) with favorable results depending on location. There were no combinations (0%) with unfavorable results at any location. These results suggest that there would be positive effects and negligible negative effects of Alternative 2 Without TUCP Delta VA on steelhead juvenile rearing and emigration.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 66.2°F upper limit of optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable results at both Keswick Dam and RBDD, and one combination (1.7%) with unfavorable results at RBDD (Table O-49). For the 59.9°F juvenile pathogen virulence threshold, there were zero to 11 combinations (0% to 18.3%) with favorable results depending on location. There were zero to one combinations (0% to 1.7%) with unfavorable results depending on location. For the 55°F upper limit of successful smoltification, there were zero to five combinations (0% to 20.0%) with favorable results depending on location. There were no combinations (0%) with unfavorable results at any location. These results suggest that there would be positive effects and negligible negative effects of Alternative 2 With TUCP systemwide VAs on steelhead juvenile rearing and emigration.

Overall, the four phases of Alternative 2 would have positive effects and negligible negative effects on water temperature conditions for steelhead juvenile rearing and emigration in the Sacramento River (Table O-49).

Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under the four phases

of Alternative 2, changes in flows may have a minor increase and/or decrease on fry and juvenile rearing habitat area. Changes in flows are expected to generally decrease fry stranding during but fry stranding may moderately increase during two of the phases of Alternative 2 in critically dry water year types. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. There would be beneficial and negligible adverse water temperature-related effects of the four phases of Alternative 2 on steelhead juvenile rearing and emigration.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). Historical data at the Fremont Weir have shown that adult steelhead migrate upstream in the Sacramento River during most months of the year, beginning in July, peaking in September, and continuing through March (Hallock 1989; McEwan 2001; Hallock et al. 1957).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During peak steelhead adult upstream migration, flows at Wilkins Slough in the Sacramento River may be increased on average in October and decreased on average in September under Alternative 2 compared to the No Action Alternative, but none of the differences are large (Table O-182 through Table O-185). CalSim 3 Sacramento River mean monthly flows at Wilkins Slough are below the minimum flow in September and October of critically dry water years under the No Action Alternative. Under the four phases of Alternative 2, flows in the Sacramento River at Wilkins Slough range from about 3,002 cfs in September of critically dry water years to about 19,920 cfs in February of wet water year types during the adult migration period. Flows in the Sacramento River at RBDD range from about 4,793 cfs in October of critically dry water years to about 37,110 cfs in February of wet water years during the adult migration period (Table O-186 through Table O-189). Under Alternative 2, Reclamation will operate minimum instream flows at 2,300 cfs in March, July, and August, and 3,250 cfs from September through February but the schedule may change in critically dry water years (WRO Order 90-5).

These results suggest that there are likely minor adverse and beneficial effects of the four phases of Alternative 2 compared to the No Action Alternative on steelhead adult migration and holding in the Sacramento River, as flows increase (6-14%) above the threshold and decrease (2-10%) below the threshold during peak migration in the lower sections of the river in critically dry water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range for minimal migration impairment during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 110 for Keswick Dam, Table 112 for Red Bluff Diversion Dam, and Table 114 for Hamilton City. Results for the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment L.1, *Sacramento River Water Temperature*

Analysis, Table 118 for Keswick Dam, Table 120 for Red Bluff Diversion Dam, and Table 122 for Hamilton City. Results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for adult migration and holding during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 126 at Keswick Dam, Table 128 for Red Bluff Diversion Dam, and Table 130 for Hamilton City.

Results for the three analyses are summarized in Table O-50. Table O-50, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 41°F to 66.2°F range for minimal migration impairment, there were zero to one month-water year type combinations (0% to 2.2% of total combinations during the period) with favorable results depending on location (Table O-50). There were zero combinations (0%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at any location. There were no combinations (0%) with unfavorable results depending on location. For the 59.9°F adult migration pathogen virulence threshold, there were zero to four combinations (0% to 8.9%) with favorable results depending on location. There were zero combinations (0%) with unfavorable results depending on location. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 2 With TUCP Without VA on steelhead adult upstream migration and holding.
- Under **Alternative 2 Without TUCP Without VA** for the 41°F to 66.2°F range for minimal migration impairment, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at any location (Table O-50). There were zero combinations (0%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were zero to one combination (0% to 2.2%) with favorable results depending on location. There were zero combinations (0%) with unfavorable results depending on location. For the 59.9°F adult migration pathogen virulence threshold, there were one to four combinations (2.2% to 8.9%) with favorable results depending on location. There were zero combinations (0%) with unfavorable results depending on location. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 2 Without TUCP Without VA on steelhead adult upstream migration and holding.
- Under **Alternative 2 Without TUCP Delta VA** for the 41°F to 66.2°F range for minimal migration impairment, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at any location (Table O-50). There were also zero combinations (0%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at any location. There were zero to one combinations (0% to 2.2%) with unfavorable results depending on location. For the 59.9°F adult migration pathogen virulence threshold, there were zero to four combinations (0% to 8.9%) with favorable results depending on location. There were zero to one combinations (0% to 2.2%) with unfavorable results depending on location. These results suggest that there would be

positive water temperature-related effects and negligible negative effects of Alternative 2 Without TUCP Delta VA on steelhead adult upstream migration and holding.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 41°F to 66.2°F range for minimal migration impairment, there were zero month-water year type combinations (0% of total combinations during the period) with favorable results depending on location (Table O-50). There were zero to one combinations (0% to 2.2%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at any location. There were zero to one combinations (0% to 2.2%) with unfavorable results depending on location. For the 59.9°F adult migration pathogen virulence threshold, there were zero to four combinations (0% to 8.9%) with favorable results depending on location. There were zero to one combination (0% to 2.2%) with unfavorable results depending on location. These results suggest that there would be negligible water temperature-related effects of Alternative 2 Without TUCP Systemwide VAs on steelhead adult upstream migration and holding.

Overall, the four phases of Alternative 2 would have positive effects and negligible negative effects on water temperature conditions for steelhead juvenile rearing and emigration in the Sacramento River (Table O-50).

Sacramento River Pulse Flows

There may be beneficial impacts of spring pulse flows on adult migration through decreased travel time.

Summary

There are expected minor beneficial and minor adverse impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison with the No Action Alternative. Under the four phases of Alternative 2 compared to the No Action Alternative, changes in flows are expected to have negligible impacts in the upper river and minor beneficial and minor adverse impact in the lower river for migrating adult steelhead. Spring pulse flow events may decrease travel time for adult migrants. Alternative 2 would have beneficial and negligible adverse effects on steelhead adult upstream migration and holding in the Sacramento River.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Similar to the adult migration section above, a flow threshold of 3,250 cfs has been used to evaluate the potential for adverse effects on steelhead kelts (Bureau of Reclamation 2019). Flows in the Sacramento River rarely drop below this level, and adults have not been observed to experience passage delays, crowding, or other adverse effects at this flow. Therefore, it represents a reasonable threshold for evaluating the potential for adverse effects on kelt emigration in the Sacramento River.

During the steelhead kelt emigration period, CalSim 3 modeled Sacramento River mean monthly flows do not go below the threshold of 3,250 cfs at Keswick Dam, RBDD, Wilkins Slough or Hamilton City under the four phases of Alternative 2 and the No Action Alternative (Table O-182 through Table O-197). These results suggest flows are adequate for kelt emigration in the Sacramento River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F migration impairment limit during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 146 for Keswick Dam, Table 148 for Red Bluff Diversion Dam, and Table 150 for Hamilton City. Full results for the percent of months with water temperature above the 69.8°F lethal limit to kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 154 for Keswick Dam, Table 156 for Red Bluff Diversion Dam, and Table 158 for Hamilton City. Full results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 162 for Keswick Dam, Table 164 for Red Bluff Diversion Dam, Table 166 for Hamilton City.

Results for the three analyses are summarized in Table O-51. Table O-51, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 66.2°F migration impairment limit, there were zero to one month-water year type combinations (0% to 4.0% of total combinations during the period) with favorable results depending on location (Table O-51). There were no combinations (0%) with unfavorable results at all locations. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at all locations. There were also no combinations (0%) with unfavorable results depending at all locations. For the 59.9°F adult migration pathogen virulence threshold, there were zero to ten combinations (0% to 40.0%) with favorable results depending on location. There were no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 2 With TUCP Without VA on steelhead kelt emigration.

- Under **Alternative 2 Without TUCP Without VA** for the 66.2°F migration impairment limit, there were zero to two month-water year type combinations (0% to 8.0% of total combinations during the period) with favorable results depending on location (Table O-51). There were no combinations (0%) with unfavorable results at all locations. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at all locations. There were also no combinations (0%) with unfavorable results depending at all locations. For the 59.9°F adult migration pathogen virulence threshold, there were zero to 10 combinations (0% to 40.0%) with favorable results depending on location. There were no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 2 Without TUCP Without VA on steelhead kelt emigration.
- Under **Alternative 2 Without TUCP Delta VA** for the 66.2°F migration impairment limit, there were zero to two month-water year type combinations (0% to 8.0% of total combinations during the period) with favorable results depending on location (Table O-51). There were no combinations (0%) with unfavorable results at all locations. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at all locations. There were no combinations (0%) with unfavorable results depending at all locations. For the 59.9°F adult migration pathogen virulence threshold, there were 0 to seven combinations (0% to 28.0%) with favorable results depending on location. There were no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 2 Without TUCP Delta VA on steelhead kelt emigration.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 66.2°F migration impairment limit, there were zero to two month-water year type combinations (0% to 8.0% of total combinations during the period) with favorable results depending on location (Table O-51). There were no combinations (0%) with unfavorable results at all locations. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at all locations. There were no combinations (0%) with unfavorable results depending at all locations. For the 59.9°F adult migration pathogen virulence threshold, there were one to seven combinations (4% to 28.0%) with favorable results depending on location. There were no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 2 Without TUCP Systemwide VAs on steelhead kelt emigration.

Overall, the four phases of Alternative 2 would have positive effects on water temperature conditions for steelhead juvenile rearing and emigration in the Sacramento River, although positive effects are muted under Alternative 2 Without TUCP Systemwide VAs relative to the other phases of Alternative 2 (Table O-51).

<u>Sacramento River Pulse Flows</u>

There may be beneficial impacts of spring pulse flows on kelt emigration through decreased travel time.

Summary

There are expected beneficial impacts of seasonal operations on steelhead kelts based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under the four phases of Alternative 2, changes in flows are expected to be above the minimum flow to avoid crowding and passage delays from Keswick Dam to Hamilton City in the Sacramento River. Spring pulse flow events may decrease travel time for kelt emigration. Alternative 2 would cause beneficial effects to steelhead kelt migration in the Sacramento River.

O.5.10.2 Clear Creek

Spawning and Egg Incubation

In Clear Creek, the temporal distribution of redd count data shows spawning December through April, with peak spawning January (Schaefer et al. 2019; Provins and Chamberlain 2019a, 2019b, 2020). Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional 2-4 weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In Clear Creek, estimated incubation timing based on spawning is late-December through late-May.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under the four phases of Alternative 2, mean spawning WUA increases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The greatest increase in estimated spawning habitat is an 7.3% increase in dry water year types under all four phases of Alternative 2. There are no anticipated reductions in mean spawning WUA under the four phases of Alternative 2 in comparison to the No Action Alternative.

The mean values of spawning WUA by month are higher under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The four months of spawning are expected to have similar spawning WUA values.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that steelhead spawning habitat in Clear Creek may have a minor decrease (0.5-1%) in January and March, and a minor increase (4.2%) in February for the four phases of Alternative 2 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The two spawning habitat analyses based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 may have a beneficial effect (up to 7.3% increase) in steelhead spawning habitat in Clear Creek across all water year types when compared to the No Action Alternative, and that spawning habitat will likely decrease in January/March and increase in February on a monthly scale in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis* Table 138 for Clear Creek at Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 144 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 174 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-52. Table O-52, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 45°F to 55°F range for successful spawning, there was one month-water year type combination (3.3% of total combinations during the period) with both favorable and unfavorable results below Whiskeytown Dam (Table O-52). For the 59.9°F adult pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 45°F to 52°F range for optimal egg incubation, there was one combination (2.9%) with both favorable and unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA steelhead spawning and egg incubation in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA** were identical to those for Alternative 2 With TUCP Without VA (Table O-52).
- Results for **Alternative 2 Without TUCP Delta VA** were identical to those for Alternative 2 With TUCP Without VA (Table O-52).
- Under **Alternative 2 With TUCP Systemwide VA** for the 45°F to 55°F range for successful spawning, there was one month-water year type combination (3.3% of total combinations during the period) with both favorable and unfavorable results below Whiskeytown Dam (Table O-52). For the 59.9°F adult pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 45°F to 52°F range for optimal egg incubation, there was one combination (2.9%) with favorable results and two combinations (5.7%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP systemwide VAs on steelhead spawning and egg incubation in Clear Creek.

Overall, the four phases of Alternative 2 would have similar negligible effects on water temperature conditions for steelhead spawning in Clear Creek (Table O-52).

Summary

There are expected minor to moderate beneficial impacts of seasonal operations on steelhead spawning and egg incubation based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under the four phases of Alternative 2, changes in flows may have a beneficial impact on spawning habitat (up to 7.3% increase) across all water year types. Water temperatures outside of the successful spawning range and optimal egg incubation range will have similar negligible impacts in Clear Creek below Whiskeytown Dam.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in Clear Creek. The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station in lower Clear Creek indicates outmigration into the Sacramento River with median passage starting in November and ending in June, with peak passage between April and June (Schraml and Chamberlain 2019a, 2019b, 2020, 2021).

Potential Changes to Steelhead from Seasonal Operations

Fry Rearing Habitat Analysis

Under the four phases of Alternative 2, mean fry rearing WUA increases in dry water year types and decreases in all other water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The greatest increase in estimated fry rearing habitat is a 0.7% increase in dry water year types under all four phases of Alternative 2. The greatest reduction in estimated fry rearing habitat is a 0.65% decrease in critically dry water year types under Alternative 2 With TUCP Without VA in comparison to the No Action Alternative.

The mean values of fry rearing WUA by month are slightly higher March through May and slightly lower February and June under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The five fry rearing months are expected to have similar fry rearing WUA values.

The results of the fry rearing habitat analysis suggest that the four phases of Alternative 2 may have a negligible (less than 1%) increase and/or decrease in steelhead estimated fry rearing habitat across all water year types in comparison to the No Action Alternative in Clear Creek.

Juvenile Rearing Habitat Analyses

Under the four phases of Alternative 2, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under the four phases of Alternative 2 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between the four phases Alternative 2 and the No Action Alternative is a 5.7% decrease in below normal water year types under Alternative 2 Without TUCP Without VA. On average across all water year types and phases of Alternative 2, there is a 3.6-4.4% reduction in estimated juvenile rearing habitat.

The mean values of juvenile rearing WUA by month are lower July through October and higher in November and December under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the six months, December is expected to have the highest juvenile rearing WUA values under Alternative 2.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for steelhead in Clear Creek may decrease 1.2-15% in February and June through October and may increase 5.2-12.6% November through January and March through May under the four phases of Alternative 2 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest decrease in estimated juvenile rearing habitat may occur in June and the greatest increase in juvenile rearing habitat may occur in May.

The results of the two steelhead juvenile rearing habitat analyses based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 may have a negative effect, as rearing habitat may decrease up to 5.7% depending on the water year type and phase in comparison to the No Action Alternative, and may increase and decrease throughout the year on a monthly scale. The steelhead juvenile rearing WUA analysis in Attachment O.1, *Clear Creek Weighted Usable Area Analysis*, analyzed the period between July and December, but some juveniles may rear year-round in Clear Creek, up to four years before emigration to the ocean. The greatest decrease in estimated juvenile rearing habitat may occur in July and the greatest increase in juvenile rearing habitat may occur in May.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperature range year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 186 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 194 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 55°F upper limit of successful smoltification during January through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 202 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-53. Table O-53, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 66.2°F upper limit of optimum temperature range for juvenile steelhead growth, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results below Whiskeytown Dam (Table O-53). For the 59.9°F juvenile pathogen virulence threshold, there were no combinations (0%) with favorable and unfavorable results results below Whiskeytown Dam. For the 55°F upper limit of successful smoltification, there were no combinations (0%) with either favorable or

unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on juvenile steelhead rearing and emigration in Clear Creek.

- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-53).

Overall, the four phases of Alternative 2 would have no anticipated effects on water temperature conditions for juvenile steelhead rearing and emigration in Clear Creek (Table O-53).

Summary

There are expected adverse impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under the four phases of Alternative 2, changes in flows are expected to have a negligible impact on fry rearing habitat and a minor to moderate adverse impact on juvenile rearing habitat. However, there would be no water temperature-related effects.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). In Clear Creek, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as August and throughout February (Killam 2022).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the period of adult steelhead migration and holding in Clear Creek, the mean monthly flows under the four phases of Alternative 2 will generally be reduced August through October and increased November through February compared to the No Action Alternative (Table O-218 through Table O-221). Throughout the full simulation period, flows on average will range from 10-21% reduction. Flows are above 100 cfs in Clear Creek throughout this period under Alternative 2. These results suggest there are negligible effects of flow to steelhead kelt emigration under the four phases of Alternative 2.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range for minimal migration impairment during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 116 for below Whiskeytown Dam. Results for the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 124 for below Whiskeytown Dam. Results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for adult migration and holding during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 32 for below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-54. Table O-54, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 41°F to 66.2°F range for minimal migration impairment, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results below Whiskeytown Dam (Table O-54). For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable and unfavorable results below Whiskeytown Dam. For the 59.9°F pathogen virulence threshold for adults, there were no combinations (0%) with favorable and unfavorable results below Whiskeytown Dam. These results suggest that there would be no effect of Alternative 2 With TUCP Without VA on steelhead adult upstream migration and holding in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-54).

Overall, the four phases of Alternative 2 would have no effect on water temperature conditions for steelhead adult upstream migration and holding in Clear Creek (Table O-54).

Summary

There are anticipated minor adverse impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison with the No Action Alternative. Under Alternative 2 compared to the No Action Alternative, Clear Creek flows are likely adequate for migrating adults. However, there would be no water temperature-related effects.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the period of steelhead kelt emigration in Clear Creek, the mean monthly flows under the four phases of Alternative 2 compared to the No Action Alternative will be reduced towards the tail ends of emigration and increased during peak emigration (Table O-218 through Table O-221). Throughout the full simulation period, flows on average will have a 10% reduction in February and a 31% reduction in June under Alternative 2. Throughout the full simulation

period, flows on average will have a 15-36% increase March through May under Alternative 2. Flows are above 100 cfs in Clear Creek from February through March under Alternative 2, which are likely adequate for emigrating kelts.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F migration impairment limit during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 152 for below Whiskeytown Dam. Full results for the percent of months with water temperature above the 69.8°F lethal limit to kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 160 for below Whiskeytown Dam. Full results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 168 for below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-55. Table O-55, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 66.2°F kelt migration impairment limit, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-55). For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F pathogen virulence threshold for adult migration, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be no effects of Alternative 2 With TUCP Without VA on steelhead kelt migration in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-55).

Overall, the four phases of Alternative 2 would have similar no effects on water temperature conditions for steelhead kelt migration in Clear Creek (Table O-55).

Summary

There are expected negligible impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison with the No Action Alternative. Under the four phases of Alternative 2 compared to the No Action Alternative, flows are likely adequate for the small proportion of the population that emigrate as kelts in Clear Creek. Water temperatures above the three temperature criteria for kelts are not anticipated to change in frequency in Clear Creek below Whiskeytown Dam under the four phases of Alternative 2 in comparison to the No Action Alternative.

O.5.10.3 Lower American River

Spawning and Egg Incubation

In the lower American River, redd surveys have reported spawning January through mid-April, with peak spawning in February (Sweeney et al. 2021). The median months of spawning from 2002-2021 were from January through March. Redd surveys on the lower American River do not occur until the first week of January, and there are reports from the Sacramento Water Forum (2015) that indicate spawning starts in late December. Therefore, the timing window of spawning on the lower American River was analyzed from late December until March.

Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional 2-4 weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). On the lower American River, egg incubation starts in late December and ends in late May, with peak incubation between February and April (Hannon pers. comm. 2023; Sacramento Water Forum 2015).

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under the four phases of Alternative 2, lower American River steelhead mean spawning WUA is highest in critically dry water years and steadily falls with wetter year types (Attachment M.3, *American River Weighted Usable Area Analysis*). This pattern of variation occurs because streamflows during the January through March spawning season of steelhead under the four phases of Alternative 2 rise from dry to wetter water year types (Table O-226 through Table O-229). The lower American River steelhead spawning WUA curve peaks at about 2,000 cfs (Attachment M.3, *American River Weighted Usable Area Analysis*) and flows under the four phases of Alternative 2 are consistently well above this level in the wetter water years. February flows are especially high in all but critically dry water years and consequently February shows the lowest spawning WUAs (Attachment M.3, *American River Weighted Usable Area Analysis*). Mean spawning WUA is consistently lower under the four phases of Alternative 2 than under the No Action Alternative, but the differences are small, ranging from 0.3% lower under Alternative 2 Without TUCP Systemwide VA in wet water years to 4.4% lower under the same phase of Alternative 2 in critically dry water years (Attachment M.3, *American River Weighted Usable Area Analysis*).

The results of the SIT LCM habitat model for the four phases of Alternative 2 are generally the same as those described above, showing small decreases (1.1- 2.7%) in spawning habitat in comparison to the results for the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

Overall, the results indicate that mean spawning WUA for steelhead under the four phases of Alternative 2 is lower than under the No Action Alternative, but all reductions are small.

Redd Dewatering Analysis

The results of the analysis for redd dewatering potential for lower American River steelhead indicate that redd dewatering is much greater in wetter water years than in drier water years for

the four phases of Alternative 2 (Attachment M.1, *American River Redd Dewatering Analysis*). This difference reflects the greater frequency of larger flow fluctuations in wetter years. Redd dewatering potential is consistently similar or higher under the four phases of Alternative 2 than under the No Action Alternative, except for a 15.3% reduction for Alternative 2 Without TUCP Systemwide VA, and the percent difference increases from wet to dry or critically dry water years (Attachment M.1, *American River Redd Dewatering Analysis*). The differences range from essentially no differences in wet years for all four phases to a 40.0% increase for Alternative 2 Without TUCP Without VA in critically dry water years. This increase, although large in relative terms, corresponds to an absolute change of only 1.8%. For the individual months of steelhead spawning in the lower American River, redd dewatering potential is highest and most variable in February for both the No Action Alternative and the four phases of Alternative 2 (Attachment M.1, *American River Redd Dewatering Analysis*). This occurs because flows during the two-month incubation period following February spawning exhibit greater declines Table O-226Table O-229).

Overall, the results indicate that the four phases of Alternative 2 increase in redd dewatering potential of steelhead relative to the No Action Alternative. The increases are especially large for dry and critically dry years, although on an absolute difference scale the largest difference is 31.8%.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 20 for Hazel Avenue and Table 22 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold for spawning adults during December through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 24 for Hazel Avenue and Table 26 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 40 for Hazel Avenue and Table 42 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold during December through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 44 for Hazel Avenue and Table 46 for Watt Avenue.

Results for the four analyses are summarized in Table O-56. Table O-56, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.13.3.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 45°F to 55°F range for successful spawning there were there were no month-water year type combinations (0%) with favorable or unfavorable results at both Hazel Avenue and Watt Avenue (Table O-56). For the 59.9°F spawning pathogen virulence threshold, there were no month-water year type combinations (0%) with favorable or unfavorable results at both Hazel Avenue and Watt

Avenue. For the 45°F to 52°F range for optimal egg incubation there were one and two month-water year type combinations (3.3% and 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were no month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 59.9°F fry pathogen virulence threshold there were zero and one month-water year type combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and zero month-water year type combinations (3.3% and 0%, respectively) unfavorable results at Hazel Avenue and Watt Avenue, respectively.

- Under **Alternative 2 Without TUCP Without VA** for the 45°F to 55°F range for successful spawning there were there were zero month-water year type combinations (0%) with favorable or unfavorable results at both Hazel Avenue and Watt Avenue (Table O-56). For the 59.9°F spawning pathogen virulence threshold, there were zero month-water year type combinations (0%) with favorable or unfavorable results at both Hazel Avenue and Watt Avenue. For the 45°F to 52°F range for optimal egg incubation there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue. There were zero and one month-water year type combinations (0% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold there were zero month-water year type combinations (0%) with both favorable and unfavorable results at Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Delta VA** for the 45°F to 55°F range for successful spawning there were zero month-water year type combinations (0%) with both favorable and unfavorable results at Hazel Avenue and Watt Avenue (Table O-56). There were zero and one month-water year type combinations (0% and 5%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F spawning pathogen virulence threshold, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue. For the 45°F to 52°F range for optimal egg incubation there was one and zero month-water year type combinations (3.3% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and zero month-water year type combinations (3.3% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold there were zero and one month-water year type combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water year type combinations (6.7% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 45°F to 55°F range for successful spawning there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-56). There were zero and one month-water year type combinations (0% and 5%, respectively), with unfavorable results at both Hazel Avenue and Watt Avenue, respectively. For the 59.9°F spawning pathogen virulence threshold, there were zero month-water year type combinations (0%) with favorable or unfavorable results at both Hazel Avenue and Watt Avenue. For the 45°F to 52°F range for optimal egg incubation there was one month-

water year type combination (3.3%) with favorable results at both Hazel Avenue and Watt Avenue,. There were one and zero month-water year type combinations (3.3% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold there were zero and one month-water year type combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water year type combinations (6.7% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, the four phases of Alternative 2 would have similar positive (3.3% - 6.7% favorable) and negative (3.3% - 6.7% unfavorable) water temperature-related effects to steelhead spawning and egg incubation in the lower American River.

Summary

There are expected minor adverse and minor beneficial impacts of seasonal operations on steelhead spawning and egg incubation in the lower American River based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are expected to have a minor decrease on spawning habitat area and a minor increase of redd dewatering potential. Water temperatures above the four spawning and egg incubation criteria have similar increases and decreases in frequency in the lower American River.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Yearling rearing is year-round in the lower American River. Young of the year fry rearing is from February through May (Sacramento Water Forum 2015). The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station in the lower American River indicates outmigration into the Sacramento River with median passage starting in January and ending in May, with peak passage between March and May (Day 2022a).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During steelhead rearing in the lower American River, the mean monthly flows under the four phases of Alternative 2 compared to the No Action Alternative are reduced in the late summer and fall, and increased some months in the spring under critically dry water year types, which may alter their rearing habitat (Table O-230 through Table O-233; Table O-226 through Table O-229). Reductions under Alternative 2 are anticipated in September through November of critically dry years when flows are below 1,000 cfs. The greatest increase in flows under Alternative 2 occur in April of a critically dry water year type (up to 1321% in the lower American River at H St) which may benefit young of the year steelhead fry rearing, but flows are expected to decrease in February and May (10-30%) under the same water year type. The greatest reduction occurs in May of a critically dry water year type (27% in the lower American River at H St).

The CalSim 3 simulated flow results suggest that changes in flow in the lower American River under the four phases of Alternative 2 compared to the No Action Alternative may have a minor adverse and a minor beneficial effect on both juvenile and fry rearing habitat during critically dry water year types. There are no reliable estimates for steelhead juvenile rearing habitat using weighted usable area analyses. USFWS 1985 derives spawning and rearing weighted usable area on fall-run Chinook salmon, but this study did not assess steelhead and has not been peer reviewed.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 48 for Hazel Avenue and Table 50 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F rearing and outmigration pathogen virulence threshold year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 52 for Hazel Avenue and Table 54 for Watt Avenue. Full results of the analysis assessing water temperatures above the percent of months with water temperature above the 55°F limit of successful smoltification during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 56 for Hazel Avenue and Table 58 for Watt Avenue.

Results for the three analyses are summarized in Table O-57. Table O-57, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.13.3.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels, there were two and one month-water year type combinations (3.3% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-57). There were one and two month-water year type combinations (1.7% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F juvenile rearing and outmigration pathogen virulence threshold, there were zero and one month-water year type combinations (0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There was one and zero month-water year type combinations (1.7% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 55°F limit of successful smoltification, there were one and zero month-water year type combinations (4% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Without VA** for the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels, there were four and one month-water year type combinations (6.7% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-57). There

were one month-water year type combinations (1.7%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59.9°F juvenile rearing and outmigration pathogen virulence threshold, there was zero and one month-water year type combinations (0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue. There were zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 55°F limit of successful smoltification, there were zero month-water year type combinations (0%) with favorable and unfavorable results at Hazel Avenue and Watt Avenue.

- Under **Alternative 2 Without TUCP Delta VA** for the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels, there were three and two month-water year type combinations (5% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-57). There were three and zero month-water year type combinations (5% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F juvenile rearing and outmigration pathogen virulence threshold, there was zero and one month-water year type combinations (0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water year type combinations (3.3% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 55°F limit of successful smoltification, there were zero and one month-water year type combinations (0% and 4%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels, there was one month-water year type combination (1.7%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-57). There were three and zero month-water year type combinations (5.0% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F juvenile rearing and outmigration pathogen virulence threshold, there were zero and two month-water year type combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water year type combinations (3.3% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 55°F limit of successful smoltification, there were one and zero month-water year type combinations (4.0% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue.

Overall, the four phases of Alternative 2 would have similar positive (1.7% - 6.7% favorable) and negative (1.7% - 5% unfavorable) water temperature-related effects to steelhead juvenile rearing and emigration in the lower American River.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration in the lower American River based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under Alternative 2 in critically dry water year types, reductions in flows may decrease rearing habitat area (February, May, October through December) and increases in flows may increase rearing habitat area (March, April, and June). Water temperatures above the three juvenile rearing and emigration criteria have similar increases and decreases in frequency in the lower American River.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). In the lower American River, adult steelhead migration may occur as early as July and through early April, with peak abundance in January and February (Sacramento Water Forum 2015; Hallock 1989; Hallock et al. 1957).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Flows in the lower American River below Nimbus Dam will be lower under the four phases of Alternative 2 compared to the No Action Alternative during the initial months of steelhead adult migration and holding, but are expected to be similar during peak migration (Table O-226 through Table O-233). Peak steelhead adult migration in the lower American River occurs between January and February (Sacramento Water Forum 2015), when flows are expected to be less than a 18% increase or decrease under the four phases of Alternative 2 across all water year types. The largest reductions in flow under the four phases of Alternative 2 for peak adult migration occur in January of critically dry water year types, but flows are expected to be above 1,000 cfs during this period. Throughout the adult migration period, November has the greatest reductions in flow under Alternative 2, with an up to 21% reduction in critically dry water year types. Flows in October (and December in some phases) of critically dry water year types are expected to be below 1,000 cfs under Alternative 2 but are likely still adequate for adult migration. These results of the CalSim 3 simulated flows suggest that there may be a negligible impact of the four phases of Alternative 2 compared to the No Action Alternative on steelhead adult migration and holding in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range of minimal migration impairment for adult steelhead during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 8 for Hazel Avenue and Table 10 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 12 for Hazel Avenue and Table 14 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult upstream migration and holding pathogen virulence threshold during July through April are presented in Attachment M.2,

American River Water Temperature Analysis, Table 16 for Hazel Avenue and Table 18 for Watt Avenue.

Results for the three analyses are summarized in Table O-58. Table O-58, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.13.3.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead there were two and one month-water year type combinations (4.0% and 2.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-58). There were zero and one month-water year type combinations (0.0% and 2.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there were two and zero month-water year type combinations (4.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and three month-water year type combinations (0.0% and 6.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F adult upstream migration and holding pathogen virulence threshold, there were zero and one month-water year type combinations (0% and 2.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Without VA** for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead there were four and one month-water year type combinations (8.0% and 2.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-58). There was one month-water year type combination (2.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 69.8°F upper lethal limit to adult migrants, there were one and zero month-water year type combinations (2.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and two month-water year type combinations (2.0% and 4.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F adult upstream migration and holding pathogen virulence threshold, there were zero and one month-water year type combinations (0.0% and 2.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Delta VA** for the for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead there were three and two month-water year type combinations (6.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-58). There were one and zero month-water year type combinations (2.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there were one and zero month-water year type combinations (2.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There

were zero and three month-water year type combinations (0.0% and 6.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F adult upstream migration and holding pathogen virulence threshold, there were zero and one month-water year type combinations (0.0% and 2.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead there was one month-water year type combination (2.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-58). There were two and zero month-water year type combinations (4.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there were two and one month-water year type combinations (4.0% and 2.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and four month-water year type combinations (0.0% and 8.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F adult upstream migration and holding pathogen virulence threshold, there were zero and two month-water year type combinations (0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at Hazel Avenue and Watt Avenue.

Overall, the four phases of Alternative 2 would have similar positive (2% - 8% favorable) and negative (2% - 8% unfavorable) water temperature-related effects to steelhead adult upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There are expected minor adverse and minor beneficial impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison with the No Action Alternative. Under Alternative 2 compared to the No Action Alternative, reductions in lower American River flows in dry and critically dry water year types may cause crowding and delays for adult migrants in October and November, but there are likely adequate flows during peak adult migration and holding. Water temperatures above all three temperature criteria both increase in frequency and decrease in frequency (2-8%) in the lower American River under the four phases of Alternative 2 in comparison to the No Action Alternative, depending on the location (Hazel Ave or Watt Ave).

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Flows in the lower American River below Nimbus Dam will be similar to or higher on average under the four phases of Alternative 2 compared to the No Action Alternative during steelhead kelt emigration period (Table O-226 through Table O-233). Peak kelt emigration is likely March through May when flows are expected to be adequate for emigration under Alternative 2. The largest changes between Alternative 2 and the No Action Alternative occur in critically dry water year types, with reductions in May (up to 24%) and increases in flow in March and April (up to 113%). These results of the CalSim 3 simulated flows suggest that there may be minor beneficial and minor adverse effects of Alternative 2 compared to the No Action Alternative to kelt emigration, but flows are likely adequate for kelt emigration.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F limit of migration impairment for steelhead kelt emigration during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 28 for Hazel Avenue and Table 30 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F lethal limit for steelhead kelt emigration during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 32 for Hazel Avenue and Table 34 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F kelt emigration pathogen virulence threshold during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 36 for Hazel Avenue and Table 38 for Watt Avenue.

Results for the three analyses are summarized in Table O-59. Table O-59, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.10.3.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without V**A for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-59). There was one month-water year type combination (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 69.8°F upper lethal limit to adult migrants, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue. For the 59.9°F kelt emigration pathogen virulence threshold, there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and zero month-water year type combinations (4.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Without VA** for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead, there were 0 month-water year type

combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue (Table O-59). For the 69.8°F upper lethal limit to adult migrants, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue. For the 59.9°F kelt emigration pathogen virulence threshold, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue, respectively.

- Under **Alternative 2 Without TUCP Delta VA** for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead, there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-59). There were two and zero month-water year type combinations (8.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F kelt emigration pathogen virulence threshold, there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water year type combinations (8.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead, there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-59). There were one and zero month-water year type combinations (4.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59.9°F kelt emigration pathogen virulence threshold, there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water year type combinations (8.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, the four phases of Alternative 2 would have positive (4% favorable) and negative (4% - 8% unfavorable) water temperature-related effects to steelhead kelt emigration in the lower American River at Hazel Avenue and Watt Avenue.

<u>Summary</u>

There are expected minor adverse and beneficial impacts of seasonal operations on steelhead kelts based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison with the No Action Alternative. Under Alternative 2 compared to the No Action Alternative, flows are likely adequate for kelt emigration. In the lower American River at Watt Ave and Hazel Ave, there are adverse and beneficial water temperature impacts (less than 8% favorable/unfavorable).

O.5.10.4 Bay-Delta

Juvenile Rearing and Emigration

While juvenile steelhead can be found in all waterways of the Delta, they are seen more frequently in the main channels to their natal river systems (National Marine Fisheries Service 2009a). The San Francisco Estuary is used as a short-term outmigration corridor for juvenile steelhead but the propensity of rearing in the Delta is currently unknown (Hayes and Kocik 2014, Chapman et al. 2015, Buchanan et al. 2021). The USFWS monitoring programs (Sacramento beach seines, Sacramento trawl, and Knight's Landing RST) indicate outmigration timing from the Sacramento River with first median passage in January and last median passage in May (Columbia Basin Research, University of Washington 2024). Outmigration from the San Joaquin River is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024).

Potential Changes to Steelhead from Seasonal Operations

Zone of Influence

Differences in hydrology under the four phases of Alternative 2 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions.

With incremental decreases in OMR under all four phases of Alternative 2 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under the four phases of Alternative 2 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2, *Zone of Influence*).

Flow into Junctions

For a detailed description of how flows under the four phases of Alternative 2 may impact the flow at Head of Old River and CVP, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2, *Flow into Junctions*).

Under all four phases of Alternative 2 and for most OMR bins except -3,500, the predicted proportion of flow entering the CVP is less than the No Action Alternative, although the predicted difference was negligible (up to ± 0.0467 for Alternative 2 Without TUCP Delta VA). Exceptions include the -2,000 OMR bin, with slightly greater change in predicted proportion of flow into CVP for Alternative 2 With TUCP Without VA (-0.069) or Alternative 2 Without TUCP Without VA (-0.0631) indicating that slightly less flow will be routed into CVP under these conditions compared to the No Action Alternative.

Under all four phases of Alternative 2 and for all OMR bins, the predicted differences in proportion of flow entering the HOR compared to the No Action Alternative are negligible (either positive or negative, but always lower than ± 0.008),

Summary

Alternative 2 relative to the No Action Alternative is expected to influence flow into the HOR and CVP junctions due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impact on flow into HOR while differences at CVP are best described between phases of Alternative 2 with and without VA due to differences in flow: Alternative 2 With TUCP Without VA and without TUCP Without VA are expected to have slightly less flow into CVP at OMR -2,000 and Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA are expected to have negligible impacts on flow into CVP. Impacts of pumping under Alternative 2 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Steelhead

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on juvenile steelhead entrainment at the Delta Fish Collection Facilities.

Salvage Density and Negative Binomial

- **Alternative 2 With TUCP Without VAs**
    - Predictions from the salvage density and the negative binomial model for steelhead include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of steelhead at SWP Banks Pumping Plant for all the months December through April of all water year types Alternative 2 With TUCP Without VAs was lower or equal to predicted average monthly loss under the No Action Alternative, except for critically dry water year types with an increase in predicted loss of 2%. Predicted average monthly loss of steelhead at Banks was lower for the wet, above normal, and below normal water year types with up to a 3% reduction in predicted loss for the below normal water year types. (Table O-60). Predicted average monthly loss of steelhead at CVP Jones Pumping Plant for all the months October through April for Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for the above normal and dry water year types, with up to a 6% increase in predicted loss for the above normal water year types. For wet, above normal, and the critically dry water year type Alternative 2 With TUCP Without VAs had a lower predicted loss for steelhead at Jones compared to the No Action Alternative with up to a 5% reduction in predicted loss for the critically dry water year types (Table O-61). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.
    - Predicted average monthly salvage of juvenile steelhead at the Delta fish collection facilities for the months of December through June under Alternative 2 With TUCP Without VAs was greater than predicted loss under the No Action Alternative for most water year types, with up to 41% increase for the above

normal water year types. For the critically dry water year types, predicted loss of steelhead at Jones had a reduction of 4% for Alternative 2 With TUCP Without VAs as compared to the No Action Alternative (Table O-62). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

- **Alternative 2 Without TUCP Without VAs**
    - Predictions from the salvage density model for steelhead include mean monthly total exports. Predictions from the negative binomial loss model for steelhead include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of steelhead at SWP Banks Pumping Plant for all the months December through April and all water year types Alternative 2 Without TUCP Without VAs was lower or equal to predicted average monthly loss under the No Action Alternative, with up to a 5% decrease in predicted loss for the critically dry water year types (Table O-60). Predicted average monthly loss of steelhead at CVP Jones Pumping Plant for all the months October through April for Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for the above normal and critically dry water year types, with up to a 6% increase in predicted loss for the above normal water year types. For wet, below normal, and dry water year type Alternative 2 Without TUCP Without VAs had a lower or equal predicted loss for steelhead at Jones compared to the No Action Alternative with up to a 3% reduction in predicted loss for the below normal water year types (Table O-61). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.
    - Predicted average monthly salvage of juvenile steelhead at the Delta fish collection facilities for the months of December through June under Alternative 2 Without TUCP Without VAs was greater than predicted loss under the No Action Alternative for most water year types, with up to 36% increase for wet water year types. For the critically dry water year types, predicted loss of steelhead at Jones had a reduction of 11% for Alternative 2 Without TUCP Without VAs as compared to the No Action Alternative (Table O-62). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.
- **Alternative 2 Without TUCP With Delta VAs**
    - Predictions from the salvage density and the negative binomial model for steelhead include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.

- Predicted average monthly loss of steelhead at SWP Banks Pumping Plant for all the months December through April and all water year types Alternative 2 Without TUCP with Delta VAs was lower than predicted average monthly loss under the No Action Alternative, with up to a 8% decrease in predicted loss for the critically dry water year types (Table O-60). Predicted average monthly loss of steelhead at CVP Jones Pumping Plant for all the months October through April for Alternative 2 Without TUCP with Delta VAs was lower than predicted average monthly loss under the No Action Alternative for the wet, below normal and dry water year types, with up to a 4% decrease in predicted loss for the below normal water year types. For above normal, and critically dry water year type Alternative 2 Without TUCP with Delta VAs had a increase in predicted loss for steelhead at Jones compared to the No Action Alternative with up to a 7% increase in predicted loss for the above normal water year types (Table O-61). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of juvenile steelhead at the Delta fish collection facilities for the months of December through June under Alternative 2 Without TUCP with Delta VAs was greater than predicted loss under the No Action Alternative for wet and above normal water year types, with up to a 25% increase for wet water year types. For the below normal, dry, and critically dry water year types, predicted loss of steelhead at Jones was lower, with a reduction of up to 18% for dry water year types for Alternative 2 Without TUCP with Delta VAs as compared to the No Action Alternative (Table O-62). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

- **Alternative 2 Without TUCP Systemwide VAs**

  - Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.

  - Predicted average monthly loss of steelhead at SWP Banks Pumping Plant for all the months December through April and all water year types Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly loss under the No Action Alternative, with up to a 8% decrease in predicted loss for the critically dry water year types (Table O-60). Predicted average monthly loss of steelhead at CVP Jones Pumping Plant for all the months October through April for Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly loss under the No Action Alternative for the wet, below normal and dry water year types, with up to a 4% decrease in predicted loss for the below normal water year types. For above normal, and critically dry water year type Alternative 2 Without TUCP Systemwide VAs had a increase in predicted loss for steelhead at CVP Jones Pumping Plant compared to the No Action Alternative with up to a 7% increase in predicted loss for the above normal water year types (Table O-61). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- Predicted average monthly salvage of juvenile steelhead at the Delta fish collection facilities for the months of December through June under Alternative 2 Without TUCP Systemwide VAs was greater than predicted loss under the No Action Alternative for wet water year types, with up to a 22% increase in predicted loss. For the above normal, below normal, dry, and critically dry water year types, predicted loss of steelhead at Jones was lower, with a reduction of up to 18% for dry water year types for Alternative 2 Without TUCP Systemwide VAs as compared to the No Action Alternative (Table O-62). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

Summary

The results of the two entrainment models suggest adverse and beneficial impacts of exports under the four phases of Alternative 2 compared to the No Action Alternative, with increases and decreases in entrainment (depending on water year type), and the magnitude of the impacts varying between the two models. Differences in exports between the four phases of Alternative 2 and the No Action Alternative are expected to have moderate to substantial increases in steelhead loss in wetter water year types (22-36%) and moderate decreases in steelhead loss during drier water year types (12-18%) in the Delta at both fish facilities under the Negative Binomial model. Differences in exports between the four phases of Alternative 2 and the No Action Alternative are expected to have adverse and beneficial impacts (-8% to 7% difference) without a consistent trend with water year type on the entrainment of steelhead in the Delta at both fish facilities.

Potential Changes to Routing and Through Delta Survival of Steelhead

ECO PTM

For a detailed description of how flows under the phases of Alternative 2 may impact steelhead routing, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2).

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under all four phases of Alternative 2 ranged from less than the No Action Alternative (up to 7% less under -5,000 cfs under Alternative 2 Without TUCP without VA and Alternative 2 With TUCP Without VA) to greater than the No Action Alternative (up to 9% greater under -3,500 cfs under Alternative 2 Without TUCP Delta VA) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in Attachment I.7, *ECO-PTM.* The decrease in routing to the Interior Delta could have a beneficial effect on outmigrating juveniles while the increase in routing could have an adverse impact on outmigrating juveniles.

Mean through-Delta percent survival December through March under the four phases of Alternative 2 were not as consistent among phases of Alternative 2 as ECO-PTM routing results were. Mean through-Delta survival under the phases with no VA, Alternative 2 Without TUCP Without VA and with TUCP Without VA, ranged from less than the No Action Alternative (up to 4% less under -2,000 cfs) to greater than the No Action Alternative (up to 4% greater under -5,000 cfs) (Attachment I.7, *ECO-PTM*). Mean through-Delta survival under the phases with VA, Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA, ranged from less than the No Action Alternative (up to 5% less under -3,500 cfs) to greater than the No Action Alternative (up to 18% greater under -2,000 cfs) (Attachment I.7, *ECO-PTM*). Survival through

Delta-specific routes is discussed further in the attachment. The increase in survival under some OMR conditions under phases of Alternative 2 with VA could have a large beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have an adverse impact on outmigrating juveniles.

Summary

The quantitative model suggests depending on considered variables, flows under Alternative 2 compared with the No Action Alternative may have minor adverse or minor beneficial impacts for outmigrating juvenile steelhead in the winter and spring, dependent on OMR grouping. Alternative 2 relative to the No Action Alternative is expected to have a possible adverse or beneficial impact on survival of outmigrating juvenile steelhead depending on OMR grouping due to differences in flow.

O.5.10.5 San Joaquin River

Juvenile Emigration

The San Joaquin River is primarily documented as an outmigration corridor for juvenile steelhead (Buchanan et al. 2021). Outmigration from the San Joaquin River into the Delta is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024). RSTs in the lower Stanislaus River, a tributary to the San Joaquin River, suggests juvenile emigration into the San Joan Joaquin River starts in January and ends in June (Day 2022b).

Potential Changes to Steelhead from Seasonal Operations

Changes in flows from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative may have a negligible effect on juvenile steelhead in the San Joaquin River. During the evaluated months in the juvenile emigration period, CalSim 3 estimates of mean monthly flows at Vernalis would generally be similar or increase under Alternative 2 compared to the No Action Alternative across all water year types (Table O-242 through Table O-245). Throughout the full simulation period, average flows will range from 3,472 to 6,459 cfs under Alternative 2 during juvenile emigration.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible effect on juvenile steelhead in the San Joaquin River. Under Alternative 2, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile emigration period (Figure O-15).

Summary

The results of these two simulation models indicate there are expected negligible impacts of seasonal operations on juvenile steelhead in the San Joaquin River under the four phases of Alternative 2 in comparison with the No Action Alternative.

Adult Upstream Migration and Holding

Steelhead/rainbow trout of anadromous parentage occur at low numbers in all three major San Joaquin River tributaries. These tributaries have a higher percentage of resident rainbow trout compared to the Sacramento River and its tributaries (Zimmerman et al. 2009). Estimates of

migrating adults in the San Joaquin River are made from the CDFW angler report cards and suggest that migration starts in July, peaks in December and January, and ends in March (California Department of Fish and Wildlife 2007).

Potential Changes to Steelhead from Seasonal Operations

Changes in flows from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative may have a minor beneficial effect on adult steelhead migration and holding in the San Joaquin River in critically dry water year types. During the evaluated months in the adult migration period, CalSim 3 estimates of mean monthly flows at Vernalis would increase from June through September of critically dry water year types under Alternative 2 compared to the No Action Alternative (Table O-242 through Table O-245). Throughout the full simulation period, average flows will range from about 1,400 to 6,500 cfs under the four phases of Alternative 2.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible effect on adult steelhead migration and holding in the San Joaquin River. Under Alternative 2, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the adult migration period (Figure O-15).

Summary

There are likely negligible to minor beneficial impacts of seasonal operations on adult steelhead migration and holding in the San Joaquin River based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison with the No Action Alternative.

O.5.10.6 Stanislaus River

Spawning and Egg Incubation

Data on steelhead spawning in the Stanislaus River is limited, but adults appear to spawn primarily from January to April. In 2021, as part of the reasonable and prudent measure to accelerate steelhead monitoring and research in the NMFS (2019) Biological Opinion, CDFW initiated the Stanislaus River Life Cycle Monitoring Program. Based on the initial redd survey report, which had a late start due to COVID-19 restrictions, spawning appears to start in February and last until April (Kok and Keller 2023). Although few steelhead spawning surveys have been conducted in the Stanislaus River, spawning *O. mykiss* has been documented upstream of the Highway 120 Bridge in Oakdale, between Goodwin Dam and the Oakdale Recreation Area.

Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In the Stanislaus River, timing can only be estimated and would be January through late May.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

The results for the four phases of Alternative 2 show consistent trends of reduction in mean spawning WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the shape of the steelhead spawning WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show reduced WUA with increased flow, except at the lowest and highest flows (less than about 200 cfs and greater than about 500 cfs, respectively). CalSim 3 mean monthly flows below Goodwin Dam, which is immediately upstream of the WUA study reach, are 200 cfs or above in all water year types, with flow consistently increasing from critically dry to wet water years during all months of the December through April steelhead spawning period, except December (Table O-234 through Table O-237). The mean spawning WUA estimates for all four phases of Alternative 2 are below those for the No Action Alternative in all water year types, ranging from 1.2% lower under Alternative 2 Without TUCP Without VA in wet water years to 6.6% lower for Alternative 2 With TUCP Without VA in below normal water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The differences are generally small (<5%), which is expected because differences in the mean flow between the Phases of Alternative 2 and the No Action Alternative are relatively small (Table O-234 through Table O-237). For the individual months of the spawning period, spawning WUA is lower under the four phases of Alternative 2 than under the No Action Alternative during December through March, but is higher in April (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results of the SIT LCM model for four phases of Alternative 2 are somewhat different from those described above for the WUA analysis, showing increases in spawning habitat acreage for February through April and slight decreases in January (3.5-4.4) in comparison to the results for the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The increases for April are large (12.4%). The differences between these results and those of the spawning WUA analysis described above may be related to differences in how the results of the spawning WUA from the different spawning reaches were combined (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that mean spawning WUA for steelhead under the four phases of Alternative 2 is similar to or lower than that under the No Action Alternative, but most reductions are small, while results for the SIT spawning habitat analysis show little change except for large increases in April.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 16 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold for spawning adults during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 18 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis s*, Table 32

for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 54°F index value for egg incubation during December through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis,* Table 34 Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during December through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 36 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-63. Table O-63, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.10.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 45°F to 55°F range for successful spawning, there were zero month-water year type combinations (0.0%) with favorable results and one month-water year type combination (3.3%) with unfavorable results at Orange Blossom Bridge (Table O-63). For the 59.9°F spawning pathogen virulence threshold, there were zero month-water year type combinations (0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 45°F to 52°F range for optimal egg incubation analysis, there was one month-water year type combination (2.5%) with favorable results and two month-water year type combinations (5.0%) with unfavorable results at Orange Blossom Bridge. For the 59.9°F fry pathogen virulence threshold analysis, there were zero month-water year type combinations (0.0%) with favorable and one month-water year type combination (2.5%) with unfavorable results at Orange Blossom Bridge.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-63).

Overall, the four phases of Alternative 2 would have similar negligible water temperature-related effects to steelhead spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

<u>Summary</u>

There are expected minor adverse and minor beneficial impacts of seasonal operations on steelhead spawning and egg incubation in the Stanislaus River based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are expected to have a minor increase and/or decrease in spawning habitat area. Water temperatures outside the spawning and egg incubation criteria are expected to have negligible increases in frequency the Stanislaus River at Orange Blossom Bridge.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in the Stanislaus River. The timing of juvenile outmigration depends on the watershed and water year. RST in the lower Stanislaus River suggests juvenile emigration into the San Joan Joaquin River starts in January and ends in June (Day 2022b).

Potential Changes to Steelhead from Seasonal Operations

Rearing Habitat—WUA Analyses

The results fry rearing WUA under the four phases of Alternative 2 generally show similar mean WUA for critically dry and dry water year types and small reductions for wetter years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the steelhead fry WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show moderately reduced WUA with increased flow, especially in the two longest river segments, Orange Blossom Bridge and Riverbank. Mean fry rearing WUA under the four phases of Alternative 2 is similar to that for the No Action Alternative in all water year types, ranging from 1.3% lower for critically dry water years in three of the four phases of Alternative 2 to 3.2% higher for dry water years under all four phases of Alternative 2 (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For all four months of the fry rearing period, median rearing WUA is roughly similar or moderately higher under the four phases of Alternative 2 relative to the No Action Alternative (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results for juvenile rearing WUA under the four phases of Alternative 2 show minor increases in mean rearing WUA from critically dry to wet water year types, except for very small reductions from below normal to above normal water year types for all four phases of Alternative 2 (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Mean juvenile rearing WUA under the four phases of Alternative 2 is higher than that under the No Action Alternative in all water year types, but the differences are small, ranging from 0.2% for wet water years under Alternative 2 Without TUCP Without VA to 2.1% or 2.2% for critically dry water years under all four phases of Alternative 2. Juveniles rear year-round and juvenile rearing WUA is highest for all four phases of Alternative 2 in February, April, and May (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in median rearing WUA between the four phases of Alternative 2 and the No Action Alternative are small in most months, but the medians are lower for all phases of Alternative 2 in January and are much higher in February.

The SIT LCM habitat model provides rearing habitat results for all juveniles, not separating out the fry stage from older juveniles. The instream juvenile rearing habitat results for the four phases of Alternative 2 are similar to those described above for juvenile rearing WUA. The SIT LCM habitat model results for the four phases of Alternative 2 show minor reductions and increases, depending on the month, in rearing habitat acreages from the No Action Alternative, ranging from 0.6% lower for Alternative 2 With TUCP With Systemwide VA in June to 5.4-5.6% higher for all four phases of Alternative 2 in February (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The differences in the results from the different analyses may be related to differences in how the habitat results from the different juvenile rearing reaches were combined in the analyses.

Overall, the results indicate that mean fry and juvenile rearing WUA for steelhead is largely similar under the four phases of Alternative 2 to the means under the No Action Alternative. The results from the SIT habitat model provide similar results, showing small differences in rearing habitat between the four phases of Alternative 2 and the No Action Alternative.

Rearing Habitat—ASH Analyses

The Area of Suitable Habitat (ASH) estimates for fry and juvenile rearing varied consistently with water year type for both fry and juvenile steelhead, increasing from critically dry to wet years. This pattern of variation reflects the overall relationship between flow and ASH for both life stages determined from modeling and field studies (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in both fry and juvenile rearing ASH between the four phases of Alternative 2 and the No Action Alternative are small, which is largely consistent with the results of the rearing WUA analyses. For fry rearing, the differences in mean ASH range from 2.6% lower for dry water years under all four phases of Alternative 2 to 1.8% higher for critically dry water years under all phases of Alternative 2 except Alternative 2 With TUCP Without VA. For juvenile rearing, all differences in mean ASH are less than 0.4%, except for 2.0% to 2.4% increases in mean juvenile rearing ASH for critically dry water years under the four phases of Alternative 2 (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the rearing periods, the medians for fry rearing ASH are lower under the four phases of Alternative 2 than under the No Action Alternative in April, and there is little difference for the other months, while for juvenile rearing ASH, the medians are lower in January and April and higher in February and roughly the same in the other months (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that mean fry and juvenile rearing ASH for steelhead is largely similar under the four phases of Alternative 2 to the means under the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimal growth without food limitation year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 38 for Orange Blossom Bridge and Table 40 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 42 for Orange Blossom Bridge and Table 44 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperatures above the 55°F limit of successful smoltification during January through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 48 for Orange Blossom Bridge and Table 50 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-64. Table O-64, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.10.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 66.2°F upper limit of optimal growth without food limitation, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-64). There were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 59.9°F juvenile pathogen virulence threshold, there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. There were one and three month-water year type combinations (1.7% and 5.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 55°F limit of successful smoltification, there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were one and zero month-water year type combinations (4.0% and 0.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-64).

Overall, the four phases of Alternative 2 would have similar negligible water temperature-related effects to steelhead spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge and above the confluence of the San Joaquin River.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under the four phases of Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are expected to have minor increases and decreases in fry and juvenile rearing habitat area across all water year types in the analyses in Attachment N.1, *Stanislaus River Habitat Availability Analysis* and increases and decreases in juvenile rearing habitat area depending on the month in the analyses in Attachment O.2, *CVPIA SIT LCM Habitat Estimates*. Water temperatures above the three juvenile rearing and emigration criteria are expected to have negligible increases in frequency in the Stanislaus River under the four phases of Alternative 2.

Adult Upstream Migration and Holding

In the Stanislaus River, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as September and throughout March and can be recovered in the RST in Oakdale from November through April (Hellmair 2022; Eschenroeder et al. 2022).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Average flows in the Stanislaus River below Goodwin Dam are expected to be similar or increased during September through March under the four phases of Alternative 2 compared to the No Action Alternative (Table O-234 through Table O-241). The largest reduction in flow under Alternative 2 is a 33% decrease in January of an above normal water year type (Alternative 2 without TUCP Delta VA). The largest increase in flow under Alternative 2 is a 46% increase in February of a dry water year type (Alternative 2 without TUCP Delta VA). Average flows are expected to be lowest in September and November under the No Action Alternative and Alternative 2 during the adult migration and holding period. The major differences between the No Action Alternative and Alternative 2 in these two months are a 17% increase in below normal water year types and a 42% increase critically dry water year types in September under Alternative 2 at the mouth of the Stanislaus River.

These results of the CalSim 3 simulated flows suggest that there may be a minor beneficial effect of Alternative 2 compared to the No Action Alternative on steelhead adult migration and holding in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range of minimal migration impairment for adult steelhead during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 4 for Orange Blossom Bridge and Table 6 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 8 for Orange Blossom Bridge and Table 10 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult upstream migration and holding pathogen virulence threshold during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 12 for Orange Blossom Bridge and Table 14 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-65. Table O-65, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.10.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead, there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-65). There were also zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. For the 69.8°F upper lethal limit to adult migrants there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San

Joaquin River. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. For the 59.9°F adult upstream migration and holding pathogen virulence threshold there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River.

- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-65).

Overall, the four phases of Alternative 2 would have similar negligible water temperature-related effects to steelhead adult upstream migration and holding in the Stanislaus River at Orange Blossom Bridge and above the confluence of the San Joaquin River.

Summary

There are expected minor beneficial impacts of seasonal operations in the Stanislaus River on adult steelhead based on analyses of simulated flows and water temperature under the four phases of Alternative 2 compared to the No Action Alternative. Under Alternative 2 compared to the No Action Alternative, there are potential minor beneficial impacts of increased flow in the fall for adult migration and holding for drier water year types. Water temperatures outside the range or above the adult migration and holding criteria are not anticipated to increase or decrease in frequency under Alternative 2 compared to the No Action Alternative.

Kelt Emigration

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Average flows in the Stanislaus River below Goodwin Dam are expected to be similar during kelt emigration under the four phases of Alternative 2 compared to the No Action Alternative, with a minor increase in February and a minor decrease in April (Table O-234 through Table O-241). The largest reduction in flow is a 21% decrease under Alternative 2 in April of a below normal water year type. The largest increase in flow is a 46% increase under Alternative 2 in February of a dry water year type. Flows are expected to be lowest in February and March of drier water year types under the No Action Alternative and Alternative 2. The largest differences in these two months are 43-46% increases in February of dry and critically dry water year types under Alternative 2.

These results of the CalSim 3 simulated flows suggest that there are anticipated minor beneficial effects of the four phases of Alternative 2 compared to the No Action Alternative on steelhead kelt emigration in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F limit of migration impairment for steelhead kelt emigration during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 20 for Orange Blossom Bridge and Table 22 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F lethal limit for steelhead kelt emigration during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 24 for Orange Blossom Bridge and Table 26 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F kelt emigration pathogen virulence threshold during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 28 for Orange Blossom Bridge and Table 30 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-66. Table O-66, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.10.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 66.2°F limit of migration impairment for steelhead kelt emigration, there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-66). There were zero and two month-water year type combinations (0.0% and 8.0%, respectively) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 69.8°F lethal limit for steelhead kelt emigration there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. For the 59.9°F kelt emigration pathogen virulence threshold there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. There were one and three month-water year type combinations (4.0% and 12.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-66).

Overall, the four phases of Alternative 2 would have negative water temperature-related effects on California central valley steelhead kelt emigration in the Stanislaus River.

Summary

There are expected minor to moderate adverse and minor beneficial impacts of seasonal operations in the Stanislaus River on steelhead kelts based on analyses of simulated flows and water temperature under the four phases of Alternative 2 compared to the No Action Alternative. Under Alternative 2 compared to the No Action Alternative, there are potential minor beneficial impacts of flow for kelt emigration. Water temperatures above the limit of migration impairment and pathogens and disease threshold are expected to increase in frequency under Alternative 2 compared to the No Action Alternative.

O.5.11 Southern DPS Green Sturgeon

O.5.11.1 Sacramento River

Spawning and Egg Incubation

Southern DPS green sturgeon adults spawn primarily from April through July, although they periodically spawn in late summer and fall (as late as October). Northern DPS green sturgeon eggs hatch about a week after fertilization (at 60ºF), and incubation time of Southern DPS green sturgeon eggs is assumed to be similar (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). Because the incubation time for green sturgeon is so short, the effects analysis period for incubating eggs is considered to be the same as the spawning period, April through July, occasionally extending to October.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

During the April through July green sturgeon spawning period, CalSim 3 estimates of mean monthly flows at RBDD under all four phases of Alternative 2 range from about 5,000 cfs for April of critically dry water years to about 15,098 cfs for April of wet water years (Table O-186 through Table O-189). Mean flows during most of this period are moderate (~8,900 cfs to ~12,300 cfs) under all four phases of Alternative 2. Alternative 2 relative to the No Action Alternative is expected to have small negative effects most months (up to 10%), but flows are moderately higher for Alternative 2 Without TUCP Without VA, with Delta VA, and with Systemwide VA for April of critically dry water years (up to 25%) and for April of above normal and below normal water years under Alternative 2 Without TUCP with Systemwide VA (8%). Flows are moderately lower in June of critically dry water under all four phases of Alternative 2 (up to 8%), May of critically dry water years under all phases except Alternative 2 Without TUCP with Systemwide VA (up to 9%), and July of critically dry water years under Alternative 2 With TUCP Without VA (10%). Flows are also moderately lower under Alternative 2 Without TUCP with Systemwide VA in June of above normal, below normal, dry, and critical water years (Table O-186 through Table O-189). During the August through October period, when green sturgeon spawning occurs in occasional years, the flows under both alternatives and all phases tend to be lower than those in April through July, but the mean flows would be close to or above 6,500 cfs under all phases for all water year types in all three 3 months. Moderate reductions in mean flows from the No Action Alternative to Alternative 2 under all four phases are predicted for August and September of critically dry water years (up to 11%); however, a moderate increase in mean flows is predicted under Alternative 2 With TUCP Without VA in October of

critically dry years (8%) (Table O-186 through Table O-189). Flow levels during all spawning months under all four phases are likely to be suitable for green sturgeon spawning and egg incubation; no adverse effects are expected to result; effects may be beneficial in April of critically dry water years under three of the four phases of Alternative 2.

CalSim 3 simulations at Hamilton City predict minor reductions in mean flow under all phases of Alternative 2 during June and July of all water years. Generally, mean flows during the April through July spawning and egg incubation period are lower at Hamilton City than at RBDD but remain similar to the No Action Alternative (~7,500 cfs to ~17,600 cfs) (Table O-194 through Table O-197). Flows are predicted to moderately to substantially increase in April of critically dry water years (up to 26%) under all four phases of Alternative 2. During the August through October spawning period, the flows under both alternatives and all four phases tend to be lower than those in April through July. The mean flows for all water years in all three months under all phases are between ~6,200 cfs to ~7,400 cfs. Generally, flows during the August to October spawning period will remain similar under all four phases of Alternative 2 compared to the No Action Alternative (Table O-194 through Table O-197). If flows are not suitable for green sturgeon spawning at Hamilton City, they would likely move upstream until they find suitable flows, so effects of reduced flows under the four phases of Alternative 2 at Hamilton City are likely to be minor.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 49.3°F to 63.7°F range for spawning initiation during April through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 208 for Bend Bridge and Table 210 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 52.3°F to 60.8°F range supporting egg incubation during April through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 216 for Bend Bridge and Table 218 for Hamilton City.

Results for the three analyses are summarized in Table O-67. Table O-67, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP with VA** for the 49.3°F to 63.7°F spawning initiation range, there were zero and four month-water year type combinations (0% and 20.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-67). There were no combinations (0%) with unfavorable results below Bend Bridge and one combination (5%) with unfavorable results at Hamilton City. For the 52.3°F to 60.8°F range for egg incubation, there were no combinations (0%) with favorable or unfavorable results at both locations. These results suggest that there would be positive water temperature-related effects or negligible negative effects of Alternative 2 With TUCP with VA on green sturgeon spawning and egg incubation.

- Under **Alternative 2 Without TUCP Without VA** for the 49.3°F to 63.7°F spawning initiation range, there were zero and three month-water year type combinations (0% and 15.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-67). There were zero and one combinations (0% and 5.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 52.3°F to 60.8°F range for egg incubation, there were zero combinations (0%) with favorable and unfavorable results at Bend Bridge and Hamilton City. These results suggest that there would be positive water temperature-related effects or negligible negative effects of Alternative 2 Without TUCP Without VA on green sturgeon spawning and egg incubation.
- Under **Alternative 2 Without TUCP Delta VA** for the 49.3°F to 63.7°F spawning initiation range, there were zero and five month-water year type combinations (0% and 25.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-67). There were zero and one combinations (0% and 5.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 52.3°F to 60.8°F range for egg incubation, there were zero and one combinations (0% and 5.0%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were also zero and one combinations (0% and 5.0%, respectively) with unfavorable results Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive water temperature-related effects or negligible negative effects of Alternative 2 Without TUCP Delta VA on green sturgeon spawning and egg incubation.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 49.3°F to 63.7°F spawning initiation range, there were zero and four month-water year type combinations (0% and 20.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-67). There were zero and one combination (0% and 5%, respectively) with unfavorable results below Bend Bridge and Hamilton City, respectively. For the 52.3°F to 60.8°F range for egg incubation, there were zero and one combinations (0% and 5.0%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were zero combinations (0%) with unfavorable results at Bend Bridge and Hamilton City. These results suggest that there would be positive water temperature-related effects or negligible negative effects of Alternative 2 Without TUCP Systemwide VAs on green sturgeon spawning and egg incubation.

Overall, the four phases of Alternative 2 would have similar positive effects and negligible negative effects on water temperature conditions for green sturgeon spawning and egg incubation depending on phase, location, month, and water year type (Table O-67).

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts and possible beneficial impacts on spawning habitat depending on the Alternative 2 phase, location, month, and water year type due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have beneficial impacts and minor adverse impacts on spawning and egg incubation depending on location, month, and water year type due to differences in water temperature.

Larval and Juvenile Rearing and Emigration

The green sturgeon spawning period is from April through July, so the larval period is considered to be April through September. The green sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch. The juveniles rear in the Sacramento River from about May through December. During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). Effects of flow and water temperature on green sturgeon larvae and juveniles may occur from April through December in the Sacramento River when analyzing the two life stages together.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling for the Sacramento River at RBDD indicates that mean monthly flows during the April through September period of larval rearing are generally similar between the No Action Alternative and all four phases of Alternative 2 with a few exceptions. As described previously, moderately higher mean flows are predicted in April of the drier water year types under all four phases of Alternative 2. Under Alternative 2 With TUCP Without VA flows are predicted to moderately decrease in May through August of critically dry water years and under Alternative 2 Without TUCP with Systemwide VA flows are predicted to moderately decrease in June of all water year types except for wet water years (Table O-186 through Table O-189). Moderate increases in mean flow from No Action Alternative to Alternative 2 in April may not be substantial enough to have a positive effect on larval green sturgeon. The August and September reductions in flow from the No Action Alternative to Alternative 2 under all four phases would potentially affect green sturgeon larvae adversely because, as discussed in Section O.1.3.2.5, *Green Sturgeon, Southern DPS*, there appears to be a positive relationship between annual outflow and abundance of green sturgeon larvae and juveniles, but this conclusion is highly uncertain.

CalSim 3 modeling for the Sacramento River at Hamilton City indicates that mean monthly flows during the period of juvenile rearing and emigration, May through December, are generally similar between the No Action Alternative and all four phases of Alternative 2 except for higher flows under all phases of Alternative 2 during October and November in critically dry water years (Table O-194 through Table O-197). Reductions in flows occur in June (with TUCP Without VA and without TUCP with Systemwide VA), July (with TUCP Without VA), and September (without TUCP with Systemwide VA) of drier water years and in June (without TUCP with Systemwide VA) of above normal water years. These reductions in flow could adversely affect green sturgeon juveniles under the four phases of Alternative 2 because, as discussed in

Section O.1.3.2.5, *Green Sturgeon, Southern DPS*, there may be a positive relationship between annual outflow and abundance of green sturgeon, but this conclusion is highly uncertain.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 64.4°F upper threshold for larvae from May through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 220 for Bend Bridge and Table 222 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 66.2°F range of optimal juvenile bioenergetic performance during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 224 for Bend Bridge and Table 226 for Hamilton City.

Results for the three analyses are summarized in Table O-68. Table O-68, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 64.4°F upper water temperature limit for newly hatched larvae, there were zero and five month-water year type combinations (0% and 25.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-68). There were zero and one combinations (0% and 5%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 59°F to 66.2°F range of optimal juvenile bioenergetic performance, there were zero and one combinations (0% and 6.7%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were five and zero combinations (33.3% and 0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive or negative water temperature-related effects of Alternative 2 With TUCP Without VA on green sturgeon larval and juvenile rearing and emigration depending on location, month, and water year type.
- Under **Alternative 2 Without TUCP Without VA** for the 64.4°F upper water temperature limit for newly hatched larvae, there were one and three month-water year type combinations (5% and 15.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-68). There were no combinations (0%) with unfavorable results at Bend Bridge and Hamilton City. For the 59°F to 66.2°F range of optimal juvenile bioenergetic performance, there were zero and one combinations (0% and 6.7%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were six and zero combinations (40.0% and 0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive or negative water temperature-related effects of Alternative 2 Without TUCP Without VA on green sturgeon larval and juvenile rearing and emigration depending on location, month, and water year type.

- Under **Alternative 2 Without TUCP Delta VA** for the 64.4°F upper water temperature limit for newly hatched larvae, there were zero and six month-water year type combinations (0% and 30.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-68). There were zero (0%) with unfavorable results at Bend Bridge and Hamilton City. For the 59°F to 66.2°F range of optimal juvenile bioenergetic performance, there were zero and one combinations (0% and 6.7%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were five and zero combinations (33.3% and 0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive or negative water temperature-related effects of Alternative 2 Without TUCP Delta VA on green sturgeon larval and juvenile rearing and emigration depending on location, month, and water year type.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 64.4°F upper water temperature limit for newly hatched larvae, there were zero and five month-water year type combinations (0% and 25.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-68). There were zero and one combinations (0% and 5.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 59°F to 66.2°F range of optimal juvenile bioenergetic performance, there were zero and one combinations (0% and 6.7%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were five and zero combinations (33.3% and 0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 Without TUCP Systemwide VAs on green sturgeon larval and juvenile rearing and emigration.

Overall, the four phases of Alternative 2 would have similar positive effects and negative effects on water temperature conditions for green sturgeon larval and juvenile rearing and emigration (Table O-68).

Summary

Alternative 2 relative to the No Action Alternative is expected to have possible minor adverse impacts on rearing and emigration depending on Alternative 2 phase, location, month, and water year type due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have beneficial impacts and adverse impacts on rearing and emigration depending on location, month, and water year type due to differences in water temperature.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Sacramento River from the Delta as early as February to make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence. After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). With the extended adult holding period, effects of flow and water temperature on adult upstream migration and holding may occur from February through December.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

Flows during the February through December period of green sturgeon immigration, spawning and holding would generally be similar between Alternative 2 and the No Action Alternative at RBDD, Hamilton City, and Wilkins Slough (Table O-186 through Table O-197). Notable exceptions include substantially higher mean monthly flows under Alternative 2 at all three locations during April (without TUCP Without VA, without TUCP with Delta VA, and without TUCP with Systemwide VA) and November (all phases) of critically dry water years, and moderate flow reductions in summer months at RBDD during critically dry years for all phases (Table O-186 through Table O-197). Increases in mean flow from No Action Alternative to Alternative 2 in April and November may or may not be substantial enough to have a positive effect on larval green sturgeon. All of the more notable flow differences occur within a range of river flows (~3,000 cfs to 12,000 cfs) that are not expected to substantially affect upstream passage of migrating green sturgeon, but summer flow reductions under all phases of Alternative 2 at Hamilton City and RBDD could result in reduced habitat quality in holding pools, adversely affecting holding adults.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52°F to 69.4°F range for adult migration during April through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 204 for Bend Bridge and Table 206 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 52°F to 73.4°F range for adult holding year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 212 for Bend Bridge and Table 214 for Hamilton City.

Results for the two analyses are summarized in Table O-69. Table O-69 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%. If the exceedance or occurrence value was >10% lower under the alternative relative to the No Action Alternative, the result is termed "Favorable". If the exceedance or occurrence value was >10% higher under the alternative relative to the No Action Alternative, the result is termed "Unfavorable". The 10% value was chosen to represent a level of difference between the alternative and the No Action Alternative that could have a biologically meaningful effect on the species but considers the coarse definition in the data (e.g., a difference in just one of the 14 above normal water years represents a 7% difference). This value should not be interpreted as a significance threshold.

- Under **Alternative 2 With TUCP Without VA** for the 52°F to 69.4°F range for adult migration, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable or unfavorable results at both Bend Bridge and Hamilton City, respectively (Table O-69). For the 59°F to 73.4°F range for adult holding, there were no combinations (0%) with favorable results at both Bend Bridge and Hamilton City. There were 12 and two combinations (20.0% and 3.3%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest

that there would be negative effects and negligible positive water temperature-related effects of Alternative 2 With TUCP Without VA on green sturgeon adult upstream migration and holding.

- Under **Alternative 2 Without TUCP Without VA**, for the 52°F to 69.4°F range for adult migration, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable or unfavorable results at both Bend Bridge and Hamilton City, respectively (Table O-69). For the 59°F to 73.4°F range for adult holding, there were no combinations (0%) with favorable results at both Bend Bridge and Hamilton City. There were 13 and two combinations (21.7% and 3.3%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 2 Without TUCP Without VA on green sturgeon adult upstream migration and holding.
- Under **Alternative 2 Without TUCP Delta VA,** for the 52°F to 69.4°F range for adult migration, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable or unfavorable results at both Bend Bridge and Hamilton City, respectively (Table O-69). For the 59°F to 73.4°F range for adult holding, there were no combinations (0%) with favorable results at both Bend Bridge and Hamilton City. There were 12 and one combinations (20.0% and 1.7%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 2 without TUCP Delta VA on green sturgeon adult upstream migration and holding.
- Under **Alternative 2 Without TUCP Systemwide VAs,** for the 52°F to 69.4°F range for adult migration, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable or unfavorable results at both Bend Bridge and Hamilton City, respectively (Table O-69). For the 59°F to 73.4°F range for adult holding, there were one and zero month-water year type combinations (1.7% and 0%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were 12 and one combinations (20.0% and 1.7%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 2 without TUCP Systemwide VAs on green sturgeon adult upstream migration and holding are identical to Alternative 2 Without TUCP Without VAs (Table O-69).

Overall, the four phases of Alternative 2 would have similar negative effects on water temperature conditions for green sturgeon adult upstream migration and holding (Table O-69).

<u>Summary</u>

Alternative 2 relative to the No Action Alternative is expected to have possible beneficial impacts and adverse impacts on upstream migration and holding habitats depending on the Alternative 2 phase, location, month, and water year type due to differences in water temperature. Alternative 2 relative to the No Action Alternative is expected to have adverse impacts on upstream migration and holding depending on location, month, and water year type due to differences in water temperature.

O.5.11.2 San Joaquin River

Green sturgeon are also present in the San Joaquin River, but at considerably lower numbers than white sturgeon. Anglers have reported catching green sturgeon in the San Joaquin River and one adult green sturgeon was captured by Reclamation in April of 2020 (Root et al. 2020 [research note]). Although the reported presence of green sturgeon in the San Joaquin River coincides with the spawning migration period of green sturgeon within the Sacramento River, no evidence of spawning has been detected (Section O.1.8.2.3, *Green Sturgeon, Southern DPS*).

Potential Changes to Green Sturgeon from Seasonal Operations

CalSim 3 Flows

Since green sturgeon spawning has not been confirmed in the San Joaquin River, life stage analyses were not performed. It is assumed that adult green sturgeon could be in the San Joaquin River during all months of the year.

During the evaluated months, CalSim 3 estimates of mean monthly flows at Vernalis under all four phases of Alternative 2 range from about 673 cfs for July of critically dry water years with TUCP Without VA to over 13,000 cfs for February of wet water years with and without TUCP Without VA (Table O-242 through Table O-245). Generally, flows remain similar between The No Action Alternative and all four phases of Alternative 2. CalSim 3 results predict moderately to substantially increased flows under all four phases of Alternative 2 compared to the No Action Alternative for June through September of critically dry water years (up to 34% in July and August under all phases except Alternative 2 With TUCP Without VA) (Table O-242 through Table O-245). Increased flows are also predicted for July of above and below normal water years (up to 6%) under Alternative 2 Without TUCP with Systemwide VA (Table O-243). Because green sturgeon are uncommon in the San Joaquin River and can easily relocate to other parts of the Bay Delta system that have adequate flow, it is not anticipated that flow reductions under the four phases of Alternative 2 would have an effect on green sturgeon compared to the No Action Alternative. Increased flows predicted for the majority of the months may have a positive effect on adult green sturgeon.

Summary

Alternative 2 relative to the No Action Alternative is expected to have possible beneficial impacts on adult green sturgeon due to differences in flow. Due to the lack of information about green sturgeon life stages in the San Joaquin River, a temperature analysis was not done for this species in this geography.

O.5.11.3 Bay-Delta

Juvenile Rearing and Emigration

After hatching, larvae and juveniles migrate downstream toward the Delta. Juveniles are believed to use the Delta for rearing for the first one to three years of their lives before moving out to the ocean and are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, especially within the central Delta and Suisun Bay/Marsh (Section O.1.9.1.5, *Green Sturgeon, Southern DPS*).

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

Differences in hydrology in the Delta under the four phases of Alternative 2 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using several quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions. In addition to these two analyses, a Delta Outflow vs. Sturgeon YCI regression analysis was done for the two sturgeon species to evaluate flow effects on sturgeon year class index.

Zone of Influence

Differences in hydrology under the four phases of Alternative 2 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions.

With incremental decreases in OMR under all four phases of Alternative 2 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under the four phases of Alternative 2 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2, *Zone of Influence*).

Flow into Junctions

Alternative 2 relative to the No Action Alternative may have effects on the flow into the Head of Old River and CVP junctions due to differences in flow. These possible differences were evaluated using DSM2-HYDRO outputs. For a detailed description of how flows under the four phases of Alternative 2 may impact the flow at Head of Old River and CVP, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2, Flow into Junctions).

Under all four phases of Alternative 2 and for most OMR bins except -3,500, the predicted proportion of flow entering the CVP is less than the No Action Alternative, although the predicted difference was negligible (up to ± 0.0467 for Alternative 2 Without TUCP Delta VA). Exceptions include the -2,000 OMR bin, with slightly greater change in predicted proportion of flow into CVP for Alternative 2 With TUCP Without VA (-0.069) or Alternative 2 Without TUCP Without VA (-0.0631) indicating that slightly less flow will be routed into CVP under these conditions compared to the No Action Alternative.

Under all four phases of Alternative 2 and for all OMR bins, the predicted differences in proportion of flow entering the HOR compared to the No Action Alternative are negligible (either positive or negative, but always lower than ± 0.008),

Delta Outflow vs. Sturgeon YCI

There are currently no tools available to directly evaluate the effect of spring outflow on green sturgeon thus white sturgeon are used as a proxy species for green sturgeon. To evaluate the effect of spring outflow on green sturgeon a Delta Outflow vs Year-Class Strength[1] regression analysis was done. This analysis is a response to the NMFS Green Sturgeon Recovery Plan that suggested larval abundance and distribution may be influenced by spring and summer outflow. The recovery plan also suggested that recruitment may be highest in wet years, making water flow an influential habitat parameter (National Marine Fisheries Service 2018a:12). As noted by NMFS (2018b:12), there are correlations between white sturgeon and Delta outflow, which have previously been used to infer potential effects on green sturgeon (ICF International 2016).

In contrast to white sturgeon, there are currently no quantitative relationships established between green sturgeon and Delta flows. There appears to be a positive relationship between annual outflow and abundance in RSTs at Red Bluff Diversion Dam of green sturgeon larvae and juveniles (Heublein et al. 2017a). More recently, CDFW found that catch per unit effort of yearling juvenile green sturgeon sampled in the Delta was about 10 times as high in years following wet water years as in years following dry and critically dry water years (Beccio 2021). These factors are generally suggestive of a positive relationship with flow, but it is uncertain the extent to which such effects may reflect water operations.

The Delta Outflow Year-Class Strength regression analysis found statistically significant positive correlations between white sturgeon year-class strength and Delta outflow for April-May and March-July. The analysis is used as a surrogate for green sturgeon. For the April-May Delta outflow, the average overall YCI values would be generally similar between the four phases of Alternative 2 (10.7 to 11.2) and the No Action Alternative (11.2) (Table O-70). The same is true for the March-July Delta outflow, with the average overall YCI values for the four phases of Alternative 2 ranging from 16.3 to 16.6 compared to 16.7 for the No Action Alternative (Table O-71). Any effects of Alternative 2 on green sturgeon relative to the No Action Alternative are expected to be limited given the limited differences in average Delta flow conditions between the two alternatives over all water year types during the specified months. For more detailed information see summaries presented in Attachment J.2*, Sturgeon Year Class Index and Delta Outflow*.

Summary

Alternative 2 relative to the No Action Alternative is expected to influence flow into the HOR and CVP junctions. Alternative 2 relative to the No Action Alternative is expected to have negligible impact on flow into HOR while differences at CVP are best described between phases of Alternative 2 with and without VA due to differences in flow: Alternative 2 With TUCP Without VA and without TUCP Without VA are expected to have slightly less flow into CVP at OMR -2,000 and Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA are expected to have negligible impacts on flow into CVP. Impacts of pumping under all four phases of Alternative 2 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of

[1] Year-class strength in this case is an index of year-class abundance based on age-0 and age-1 white sturgeon abundance indices from otter trawling by the San Francisco Bay Study (Fish 2010).

riverine flow and thus more susceptible to changes in pumping (ZOI). Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on juvenile green sturgeon year class strength using white sturgeon as a proxy for green sturgeon due to differences in flow.

Potential Changes to Entrainment of Southern DPS Green Sturgeon

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on green sturgeon entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

<u>Salvage Density</u>

- **Alternative 2 With TUCP Without VAs**
    - Predictions from the salvage density model for green sturgeon include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of green sturgeon at SWP Banks Pumping Plant for the months January, and March of all water year types Alternative 2 With TUCP Without VAs was greater than or equal to predicted average monthly loss under the No Action Alternative for the wet, dry, and critically dry water year types with up to 6% increase in predicted loss for wet water year types. For above normal, and below normal water year types Alternative 2 With TUCP Without VAs had a lower predicted loss of green sturgeon at Banks compared to the No Action Alternative with up to a 4% reduction in loss for the above normal water year types (Table O-72). Predicted average monthly loss of green sturgeon at CVP Jones Pumping Plant for all the months June through July Alternative 2 With TUCP Without VAs had equal or lower predicted average monthly loss compared to the No Action Alternative, with up to a 14% reduction in predicted loss for dry water year types (Table O-73). It should be noted that loss of green sturgeon at both facilities is rare and infrequent with such low values of predicted loss, that the percent differences may not be representative. For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.
- **Alternative 2 Without TUCP Without VAs**
    - Predictions from the salvage density model for green sturgeon include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of green sturgeon at SWP Banks Pumping Plant for the months January, and March of all water year types Alternative 2 Without TUCP Without VAs was less than or equal to predicted average monthly loss under the No Action Alternative for all water year types except for the wet water year type that had an increase of 7%. For all other water year types Alternative 2 Without TUCP Without VAs had a lower or equal predicted loss of green sturgeon

at Banks compared to the No Action Alternative with up to a 4% reduction in loss for the above normal water year types (Table O-72). Predicted average monthly loss of green sturgeon at CVP Jones Pumping Plant for all the months June through July Alternative 2 Without TUCP Without VAs had equal or lower predicted average monthly loss compared to the No Action Alternative, with up to a 13% reduction in predicted loss for dry water year types (Table O-73). It should be noted that loss of green sturgeon at both facilities is rare and infrequent, with such low values of predicted loss the percent differences may not be representative. For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

- **Alternative 2 Without TUCP With Delta VAs**
    - Predictions from the salvage density model for green sturgeon include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of green sturgeon at SWP Banks Pumping Plant for the months January, and March of all water year types Alternative 2 Without TUCP with Delta VAs was less than or equal to predicted average monthly loss under the No Action Alternative for all water year types except for the wet water year type that had an increase of 4%. For all other water year types Alternative 2 Without TUCP with Delta VAs had a lower or equal predicted loss of green sturgeon at Banks compared to the No Action Alternative with up to a 18% reduction in loss for the above normal water year types (Table O-72). Predicted average monthly loss of green sturgeon at CVP Jones Pumping Plant for all the months June through July Alternative 2 Without TUCP with Delta VAs had equal or lower predicted average monthly loss compared to the No Action Alternative for all water year types, with up to a 12% reduction in predicted loss for dry water year types (Table O-73).
- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for green sturgeon include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of green sturgeon at SWP Banks Pumping Plant for the months January, and March of all water year types Alternative 2 Without TUCP Systemwide VAs was less than or equal to predicted average monthly loss under the No Action Alternative for all water year types except for the wet water year type that had an increase of 3%. For all other water year types Alternative 2 Without TUCP Systemwide VAs had a lower or equal predicted loss of green sturgeon at Banks compared to the No Action Alternative with up to a 18% reduction in loss for the above normal water year types (Table O-72). Predicted average monthly loss of green sturgeon at CVP Jones Pumping Plant for all the months June through July Alternative 2 Without TUCP Systemwide VAs had

equal or lower predicted average monthly loss compared to the No Action Alternative for all water year types, with up to a 10% reduction in predicted loss for dry water year types (Table O-73). It should be noted that loss of green sturgeon at both facilities is rare and infrequent, with such low values of predicted loss the percent differences may not be representative. For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on the entrainment of juvenile green sturgeon at both facilities due to differences in flow. Results from the quantitative model show possible beneficial impacts, but since green sturgeon are salvaged so rarely, the numbers may not be representative.

Adult Upstream Migration and Holding

Adult green sturgeon move through the Delta from February through April to get to spawning locations in the upper Sacramento River. Following their initial spawning run upriver, adults split into two out migration groups, the "early" out migration group may migrate immediately back downstream through the Delta during May and June, or the "late" out migration group may hold for a few weeks to months in the upper river before moving back downstream during November through January (Section O.1.9.1.5, *Green Sturgeon, Southern DPS*).

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

Delta Outflow vs. Sturgeon YCI

The Delta outflow vs Sturgeon YCI regression analysis results apply to all life stages of green sturgeon found in the Bay Delta. The regression analysis, used as a surrogate for green sturgeon, found statistically significant positive correlations between white sturgeon year-class strength and Delta outflow for April-May and March-July. Under the four phases of Alternative 2, April-May Delta outflow average overall YCI values would be up to 4.7% lower (Table O-70) and the March-July Delta outflow values would be up to 2.2% lower (Table O-71) compared to the No Action Alternative. Refer to the analysis in Section O.5.11.3.1, *Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible flow-related impacts on adult green sturgeon year class strength using white sturgeon as a proxy for green sturgeon.

O.5.12 Delta Smelt

O.5.12.1 Bay-Delta

Adult Migration and Spawning

During winter, adult Delta smelt initiate upstream spawning migration in association with "first flush" flow events (Sommer et al. 2011). Others report this seasonal change as a multi-directional and more circumscribed dispersal movement to freshwater areas throughout the Delta region (Murphy and Hamilton 2013). By late winter-spring, after arriving in freshwater staging habitats, adult Delta smelt hold until spawning commences during favorable water temperatures (Bennett 2005; Grimaldo et al. 2009; Sommer et al. 2011; Damon et al. 2016). Delta smelt spawn over a wide area throughout much of the Delta, including the Sacramento River and San Joaquin River confluence, the upper Sacramento River, and Cache Slough as well as into Suisun Marsh and the Napa River as conditions allow (Brown et al. 2014; Murphy and Hamilton 2013). Spawning of Delta smelt has not been observed in the wild (Moyle et al. 2016).

Potential Changes to Delta Smelt from Seasonal Operations

<u>CalSim 3 X2 Modeled X2 Position</u>

The position of X2 under Alternative 2 was similar to the No Action Alternative (Table O-198 through Table O-201) during the adult Delta smelt migration and spawning period, only varying zero to four km from the No Action Alternative, likely having negligible impacts on adult Delta smelt in the winter and spring.

<u>USFWS Delta Smelt Life Cycle Model</u>

The geometric mean of the expected rate of change in abundance across years (1995-2015), lambda (λ), for the Alternative 2 phases ranged from 0.90 to 0.94 (Attachment F.4., *Delta Smelt Life Cycle Model with Entrainment*). The geometric means of the expected population growth rate varied more widely across water year types and showed positive growth rates under wetter meteorology and negative growth rates under drier meteorology. During wet and above normal water years, λ ranged from 1.21to 1.24 under the four phases of Alternative 2 (i.e., from a 21% to a 24% increase in abundance). Conversely, changes in λ were negative during below normal, dry and critically dry water year types, with λ ranging from 0.70 to 0.73 (i.e., from a -30% to a -27% decline in abundance) during those water year types under the four phases of Alternative 2. Compared to the No Action Alternative, the results for each phase of Alternative 2 ranged from 5% lower to 4% higher in terms of population growth rates, depending on the water year type. The largest difference in growth rates compared to the No Action Alternative was predicted during wet and above normal water years, with the difference ranging from 3-5% lower depending on the Alternative 2 phase. Nevertheless, in that case both No Action Alternative and each phase of Alternative 2 resulted in population growth rates greater than 20% per year on average during wet and above normal water years (Attachment F.4., *Delta Smelt Life Cycle Model with Entrainment*).

Revised Maunder and Deriso (MDR) Life Cycle Model

Life cycle analysis with the MDR model for each of the Alternative 2 phases indicated negligible impact on Delta smelt population growth compared to the No Action Alternative. Differences in single-year λ values did not exceed +/-10% across all modeled years (1995-2015), and the geometric mean of λ was 0.75 for all Alternative 2 phases and the No Action Alternative (Attachment F.1, *Maunder and Deriso in R Model*).

In the MDR model, survival from the sub-adult to adult stage can be influenced by winter covariates which are averaged across the December to February period. Model selection retained combined Old and Middle River flow (OMR) and mean Secchi depth at South Delta monitoring stations as significant covariates of sub-adult survival, with coefficients of 0.477 and 0.542, respectively. Although differences in hydrology between the Alternatives would be expected to influence turbidity, the relationship is complex and was not able to be addressed for this analysis. Within the MDR, impacts on sub-adult survival are therefore related only to differences in OMR between the Alternatives. Mean winter OMR differed negligibly from the No Action Alternative for all of the Alternative 2 phases (-1.1% to 0.6% change), further indicating minimal potential for impacts on sub-adult to adult Delta smelt survival via the modeled pathway.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the winter in the LSZ showed significant relationships for 5 zooplankton taxa; *Daphnia* adults, decapod larvae, *Eurytemora affinis* adults, other calanoid adults, and other calanoid copepods. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 2, when compared to the No Action Alternative, for *Daphnia* adults, there was a 20% expected CPUE increase during the critically dry water year type for the with phases without VAs. There was no expected change in CPUE in the wet, above normal, below normal, and dry water year type for all phases and during the critically dry water year type for the phases with VAs. Results for decapod larvae CPUE were negligible when rounded to the nearest whole integer (values were 0) across all WYT and scenarios. *E. affinis* adults had the largest expected CPUE increase of 2% during the dry water year type for all phases and for the critically dry water year type for the without TUCP, no VA phase. There was no expected change in CPUE in the above normal water year type for the phases without VAs, and the phase with Delta VAs, in the below normal water year type for the no TUCP, Delta VA phase and in the critically dry water year type for the with TUCP Without VA phase, and phases with VAs. For other calanoid copepod adults (*Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), the largest expected CPUE increase of 6% was during the below normal water year type for the phases without VAs and the Systemwide VA phase. There was no expected change in CPUE in the wet water year type for the phases with VAs, in the above normal water year type for the phases without VAs and the Delta VA phase; similarly, CPUE wasn't expected to change in the below normal water year type for the Delta VA phase and in the dry and critically dry water year type for all phases. For other calanoid copepod copepodites (*Acartia* spp., *Acartiella* spp., unidentified calanoids, *Eurytemora affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), there was a 3% expected CPUE increase during the dry water year type for all phases and during the critically dry water year type for the without TUCP Without VA phase. There was no expected change in CPUE in the wet water year type for the phases with VAs, during the above normal water year type for the phase without VAs and the Delta VA phase, and during the critically dry water year type for phases

with VAs (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 2 during the winter were generally only slightly (<5%) different from the No Action Alternative except in January of critically dry water year types for the phases without VAs which showed an increase resulting in no to minor increases in zooplankton CPUE (Table O-206 through Table O-209).

Analysis of CPUE with outflow during the spring showed significant relationships for the 5 zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 2, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 20% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 4% during the above normal water year type for the phases without VAs. *E. affinis* adults had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal water year type for the with TUCP Without VA phase. Harpacticoids had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal water year type and the below normal water year type for the phases without VAs. Other calanoid adults had the largest expected CPUE increase of 14% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal and below normal water year type for the with TUCP no VA phase. Other calanoid copepodites had the largest expected CPUE increase of 10% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal and the below normal water year type for the phases without VAs. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflow under Alternative 2 during the spring generally decreased in May for the wet, above normal, and below normal water year types for all phases except the phase with systemwide VAs, when compared to the No Action Alternative. Flows were higher for the phase with systemwide VAs in March and April and higher in March for the phase with Delta VAs. Flows were also higher during the critically dry water year type for all phases except the with TUCP no VA phase (Table O-206 through Table O-209). As a result, zooplankton CPUE showed increases during the critically dry water year type in the spring for all phases except the with TUCP no VA phase and during the below normal, dry and critically dry water year type for the systemwide VA phase.

<u>Summary</u>

Alternative 2 relative to the No Action Alternative is expected to have beneficial to adverse impacts on adult Delta smelt migration and spawning due to differences in flow. Under Alternative 2 CPUE of Delta Smelt prey species was only minorly (<5%) different from the No Action Alternative except in January of critically dry water year types for the phases without VAs which showed an increase resulting in no to minor increases in zooplankton CPUE during the winter, while in the spring zooplankton CPUE increased during the critically dry water year type in the spring for all phases except the with TUCP no VA phase and during the below normal, dry and critically dry water year type for the systemwide VA phase. Results from the revised Maunder and Deriso life cycle model indicate that under Alternative 2 there would be minimal potential impacts on sub-adult to adult Delta smelt survival. Compared to the No Action

Alternative, the USFWS lifecycle model results for each phase of Alternative 2 ranged from being equal to No Action Alternative during below normal, dry, and critically dry dry year types to 8% lower in terms of population growth rates during wet and above normal water year types for the phases without VAs. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the winter and spring, which is expected to have negligible impacts on adult Delta smelt migration and spawning.

Potential Changes to Entrainment of Delta Smelt

Alternative 2 relative to the No Action Alternative is expected to affect the entrainment of adult Delta Smelt. Entrainment varies annually and depends on a combination of hydrology, turbidity, and export rates due to differences in flow (see Smith et al. 2021). Historic salvage shows adult Delta smelt are entrained in the Delta Fish Collection Facilities, however in more recent years fewer fish have been entrained likely due to a combination of changes to operations and the continued decline of the Delta smelt population. While the USFWS life cycle model does incorporate entrainment, it was not used to evaluate entrainment of adult Delta smelt. Instead, OMR flows were used to evaluate changes between Alternative 2 and the No Action Alternative. Assumptions and uncertainty associated with the USFWS life cycle model are found in Attachment F.4, *Delta Smelt Life Cycle Model with Entrainment*.

<u>CalSim 3 OMR Values</u>

Modeled CalSim 3 results indicated OMR combined flows under Alternative 2 when compared to the No Action Alternative were more and less negative depending on the phase and month from January to June (Table O-210 through Table O-213). There were more negative OMR flow values in April and May for the phases without VAs and in May for the phases with VAs compared to the No Action Alternative. This is expected to have an adverse effect on entrainment of adult Delta smelt. There were less negative OMR flow values in June for the phases without VAs, March and June for the phase with Delta VAs, and March, April and June for the phase with systemwide VAs, which are expected to have a beneficial effect on entrainment of adult Delta smelt.

<u>Summary</u>

Alternative 2 relative to the No Action Alternative is expected to range from adverse to beneficial impacts on the entrainment of adult Delta smelt due to differences in flow. OMR values were more negative during April and May across all water year types for the phases without VAs and in May for the phases with VAs compared to the No Action Alternative, which would have adverse impacts on adult Delta smelt entrainment. OMR values were less negative during June for phases without VAs, March, and June for the phase with Delta VAs, and March, April and June for the phase with systemwide VAs, which is expected to have beneficial impacts on adult Delta smelt entrainment.

Eggs and Larvae

Eggs hatch after an average of 10 days in the spring and planktonic larvae are transported (advected) from freshwater regions by the Sacramento River and tidal flows from March through May. The larval stage lasts for an average of 30 days. The nonpelagic habitats used by larval Delta smelt before they move into the pelagic areas are not known (Swanson et al. 1998; Sommer et al. 2011).

Potential Changes to Delta Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 2 was similar to the No Action Alternative (Table O-198 through Table O-201) during the larval Delta smelt period, only varying 0-4 km from the No Action Alternative, likely having negligible effects on larval Delta smelt in the spring.

Revised Maunder and Deriso Life Cycle Model

Life cycle analysis with the revised Maunder and Deriso Model in R (MDR) did not identify any significant covariates of recruitment, and so did not evaluate effects on eggs or early larval stages.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the spring showed significant relationships for the 5 zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 2, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 20% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 4% during the above normal water year type for the phases without VAs. *E. affinis* adults had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal water year type for the with TUCP Without VA phase. Harpacticoids had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal water year type and the below normal water year type for the phases without VAs. Other calanoid adults had the largest expected CPUE increase of 14% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal and below normal water year type for the with TUCP no VA phase. Other calanoid copepodites had the largest expected CPUE increase of 10% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal and the below normal water year type for the phases without VAs. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflow under Alternative 2 during the spring generally decreased in May for the wet, above normal, and below normal water year types for all phases except the phase with systemwide VAs, when compared to the No Action Alternative. Flows were higher for the phase with systemwide VAs in March and April and higher in March for the phase with Delta VAs. Flows were also higher during the critically dry water year type for all phases except the with TUCP no VA phase (Table O-206 through Table O-209). As a result, zooplankton CPUE showed increases during the critically dry water year type in the spring for all phases except the with TUCP no VA phase and during the below normal, dry and critically dry water year type for the systemwide VA phase.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor adverse to beneficial impacts on Delta smelt larvae depending on the Alternative 2 phase and water year type due to differences in flow. Compared to the No Action Alternative, CPUE of Delta smelt prey species is expected to minorly decrease during the wet year type (-1%) for all phases, and during all water year types except the critically dry water year type for the phases without VAs. CPUE increased during all water year types except for the wet water year type for phase with systemwide VAs and during the dry and critically dry water year type for the phase with Delta VAs. Results from the revised Maunder and Deriso life cycle model did not identify any significant covariates of recruitment, and so did not evaluate impacts on eggs or early larval stages. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the spring which are expected to have no impact on larval Delta smelt.

Potential Changes to Entrainment of Delta Smelt

Particle Tracking Model (PTM)

The CalSim 3 model simulated operational conditions under a range of OMR and inflow conditions from the Sacramento and San Joaquin rivers, with the DSM2 PTM module allowing for an assessment of entrainment of neutrally buoyant passive particles (a proxy for larval Delta smelt, generally distributed throughout the water column) at export facilities (Attachment I.8, *Particle Tracking Fate Modeling of Larval Smelt Entrainment*). PTM analysis was only considered for the larval Delta smelt life stage since modeling suggests later Delta smelt life stages are likely not neutrally buoyant and have a behavioral response to maintain horizontal position in the estuary (Gross et al. 2021, Kimmerer and Nobriga 2008). Results discussed here are expressed as percent of particles with a fate of *Entrained at Exports*. Please refer to Attachment I.3, *Delta Export Zone of Influence Analysis*, for keys to inflow and OMR bins codes, including corresponding Sacramento and San Joaquin rivers flow ranges and mean OMR and Exports flow ranges. While a complete set of detailed results is presented in Attachment I.8, *Particle Tracking Fate Modeling of Larval Smelt Entrainment*, the following narrative focuses on three injection regions when assessing potential entrainment effects from the perspective of varying inflows (Inflow bins: *Sacramento River, San Joaquin River,* and *Yolo Bypass Region*) and one injection region when assessing potential effects from the perspective of OMR net flows (OMR bins: *San Joaquin River Region*).

Inflow Bins

Depending on inflow conditions, an average of 0 to 12% of particles injected within the Sacramento River region would be entrained at export facilities under the four phases of Alternative 2, compared to 0 to 14% under the No Action Alternative. The average percentage of particles entrained at exports ranged from 28% lower than for the No Action Alternative for Alternative 2 Without TUCP Systemwide VAs under "himed" inflow conditions (1 *vs* 2%) to 63% higher than the No Action Alternative for Alternative 2 With TUCP Without VA and Alternative 2 Without TUCP Without VA under "medhi" inflow conditions (but note that the absolute entrainment remained low at around 2%).

Depending on inflow conditions, an average of 45 to 90% of particles injected within the San Joaquin River region would be entrained at export facilities under the four phases of Alternative 2, compared to 45 to 87% under the No Action Alternative. Differences in potential entrainment compared to the No Action Alternative ranged from -13% for Alternative 2 Without TUCP Delta VA and Alternative 2 Without TUCP Systemwide VA under "himed" inflow conditions to +27% for Alternative 2 With TUCP Without VA and Alternative 2 without TUCP Without VA under "medhi" inflow conditions. Although not discussed here in detail, a similar pattern was observed for other injection regions with moderate potential for particles entrainment. Alternative 2 Without TUCP Delta VA and Alternative 2 Without TUCP Systemwide VA would lead to substantial reductions in the average percentage of particles entrained compared to the No Action Alternative under "himed" inflow conditions (up to -28% for the Central Delta injection region or -30% for the Mokelumne River injection region). Alternative 2 With TUCP Without VA would lead to the largest increases in potential entrainment under "medhi" inflow conditions compared to the No Action Alternative (up to +67% for the Central Delta injection region or +64% for the Mokelumne River injection region).

Depending on inflow conditions, an average of 0 to 4% of particles injected within the Yolo Bypass region would be entrained at export facilities under the four phases of Alternative 2, compared to 0 to 5% under the No Action Alternative. Differences in potential entrainment compared to the No Action Alternative ranged from -27% under Alternative 2 Without TUCP Systemwide VAs under "medlo" inflow conditions to +64% for Alternative 2 Without TUCP Without VA under "medhi" inflow conditions (note, however, that average entrainment for this injection region remained low between 0 and 4%).

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), there was a range of -7% to +24% between the average percentage of particles entrained under all four phases of Alternative 2 and when compared to the No Action Alternative.

OMR Bins

Depending on OMR flow conditions, an average of 56 to 77% of particles injected within the San Joaquin River region would be entrained at export facilities under the four phases of Alternative 2, compared to 57 to 87% under the No Action Alternative. Potential entrainment ranged from 14% lower under Alternative 2 Without TUCP Without VA when compared to the No Action Alternative for the -5000 OMR bin (75% *vs* 87%) to 7% higher under Alternative 2 With TUCP Without VA and Alternative 2 Without TUCP Without VA for the -3500 bin (73 *vs* 68%). Although not discussed here in detail, a similar pattern was observed for other injection regions with moderate potential for particles entrainment at export facilities (Mokelumne River, Sacramento River, Central Delta): all four phases of Alternative 2 would generally lead to substantial reductions in the average percentage of particles entrained compared to the No Action Alternative for the most negative OMR index (-5000: -40 to -62%), increases for intermediate OMR index (-3500: +16% to +38%) and either little or variable change under the less negative OMR index (-2000: --13% to +27%).

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of OMR flow conditions, there was generally little difference between the average percentage of particles entrained under all four phases of Alternative 2 and under the No Action Alternative (-4 to +3%).

Summary

Alternative 2 relative to the No Action Alternative for injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta) is expected to generally have beneficial to adverse impacts on the entrainment of larval Delta smelt for all particle origins, inflow groupings, and OMR groupings due to differences in flow.

Juveniles

During and after larval rearing in freshwater, many young Delta smelt move with river and tidal currents during the early summer to remain in favorable rearing habitats, often moving into low salinity (≤ 6 psu) areas to avoid seasonally warm and highly transparent waters that typify many areas in the central Delta (Nobriga et al. 2008). Juvenile Delta smelt rearing habitat is correlated with salinity, particularly the position of the LSZ, and other habitat attributes such as turbidity and temperature. Delta smelt also rear in upstream areas such as the Cache Slough complex and Sacramento Deep Water Ship Channel, depending on habitat conditions (Sommer and Mejia 2013). Studies indicate that in fall, prior to spawning, juvenile and sub-adult Delta smelt tend to remain in the LSZ (Sommer et al. 2011), though they can be found in the lower San Joaquin River, Suisun and San Pablo bays, the Sacramento River and San Joaquin River confluence, Cache Slough, and the lower Sacramento River (Murphy and Hamilton 2013).

Potential Changes to Delta Smelt from Seasonal Operations

Alternative 2 relative to the No Action Alternative is anticipated have to effects on juvenile Delta smelt including the location and size of the LSZ (as indexed by X2 position), estimated summer and fall habitat, population growth rate, and prey availability due to differences in flow. These possible differences were evaluated using several quantitative models.

CalSim 3 X2 Modeled X2 Position

While Delta smelt can occupy a wide range of habitats and salinities, historically a majority of Delta smelt reside in or near the low salinity zone (LSZ, 0.5–6 psu) (Merz et al. 2011, Moyle et al. 1992). X2 (the location of the 2 psu salinity isohaline measured as its distance in kilometers from the Golden Gate Bridge is located) has been used as a proxy for the LSZ (MacWilliams et al. 2015, Kimmerer et al. 2013, Jassby et al. 1995). The position of X2 responds to CVP and SWP operations as well as precipitation, because more freshwater outflow through the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and at the confluence of the Sacramento and San Joaquin rivers (X2 ~ 80-85 km).

The position of X2 under Alternative 2 was similar to the No Action Alternative (Table O-198 through Table O-201) during the juvenile Delta smelt period, only varying zero to three km from the No Action Alternative, likely having negligible effects on juvenile Delta smelt in the summer and fall.

Habitat Suitability Index

Juvenile Delta smelt summer and fall habitat was estimated for different water year types (wet, above normal, below normal, dry, and critical) using the Bever et al. (2016) habitat suitability index (Bever HSI) and the Bever HSI with a water temperature threshold of 22° Celsius (22C HSI), where the Bever HSI value is multiplied by 0 when water temperature is greater than 22° C and by 1 when water temperature is less than or equal to 22° C. The temperature threshold of 22ºC was used based on sub-lethal physiological and behavioral effects observed in multiple studies (Davis et al. 2022, Hammock et al. 2022, Komoroske et al. 2021, Lewis et al. 2021, Davis et al. 2019, Komoroske et al. 2015).

Under Alternative 2 with a TUCP and without Voluntary Agreements, both the mean Bever HSI and mean 22C HSI for subregions targeted by the summer fall habitat action (Yolo Bypass, which includes the Cache Slough Complex and Sacramento Deepwater Shipping Channel; Lower Sacramento River; Confluence; Suisun Marsh; northwest Suisun Bay) were 2% lower to less than 1% higher than under the No Action Alternative, depending on water year type. The largest differences under Alternative 2 with a TUCP and without Voluntary Agreements are predicted during the below normal water year for both mean Bever HSI (2% lower) and mean 22C HSI (2% lower). The smallest differences are predicted during the above normal water year for mean Bever HSI (0%) and during the critical water year for mean 22C HSI (< 1% higher).

Under Alternative 2 without a TUCP and without Voluntary Agreements, mean Bever HSI for subregions targeted by the summer fall habitat action was 2% lower to 6% higher than under the No Action Alternative, depending on water year type. Under Alternative 2 without a TUCP and without Voluntary Agreements, the mean 22C HSI for the summer fall habitat action subregions was 2% lower to less than 1% higher than under the No Action Alternative, depending on water year type. The largest differences under Alternative 2 without a TUCP and without Voluntary Agreements are predicted during the critical water year for mean Bever HSI (6% higher) and during the below normal water year for mean 22C HSI (2% lower). The smallest differences are predicted during the above normal water year for mean Bever HSI (0%) and mean 22C HSI (< 1% higher).

Under Alternative 2 without a TUCP and with Delta Voluntary Agreements, mean Bever HSI for subregions targeted by the summer fall habitat action was 1% lower to 4% higher than under the No Action Alternative, depending on water year type. Under Alternative 2 without a TUCP and with Delta Voluntary Agreements, the mean 22C HSI for the summer fall habitat action subregions was 6% lower to 2% higher than under the No Action Alternative, depending on water year type. The largest differences under Alternative 2 without a TUCP and with Delta Voluntary Agreements are predicted during the critical water year for both mean Bever HSI (4% higher) and mean 22C HSI (6% lower). The smallest differences are predicted during the above normal water year for mean Bever HSI (< 1% higher) and during the below normal water year for mean 22C HSI (0%).

Under Alternative 2 without a TUCP and with all Voluntary Agreements, mean Bever HSI for subregions targeted by the summer fall habitat action was 1% lower to 5% higher than under the No Action Alternative, depending on water year type. Under Alternative 2 without a TUCP and with all Voluntary Agreements, the mean 22C HSI for the summer fall habitat action subregions was 4% lower to 2% higher than under the No Action Alternative, depending on water year type. The largest differences under Alternative 2 without a TUCP and with all Voluntary Agreements are predicted during the critical water year for mean Bever HSI (5% higher) and mean 22C HSI (4% lower). The smallest differences are predicted during the dry water year for mean Bever HSI (0%) and during the below normal water year type for 22C HSI (0%).

The results of the HSI analyses suggest that across all phases of Alternative 2 may result in no or minor increases (0%–6%) and minor decreases (< 1%–6%) in suitable habitat depending on water year type and the application of a temperature threshold in comparison to the No Action Alternative and would likely have negligible to minor adverse and minor beneficial impacts on juvenile Delta smelt summer and fall habitat.

Revised Maunder and Deriso Life Cycle Model

Survival between the post-larval and juvenile stages is influenced by summer variables, and model selection identified two significant covariates: cumulative June-August outflow and June-August mean water temperature with coefficients of 0.354 and -0.351, respectively (Attachment F.1, *Maunder and Deriso in R Model*). Although differences in hydrology between the alternatives would be expected to influence temperature, the relationship is complex and was not able to be addressed for this analysis. Within the MDR, impacts on post-larval survival are therefore related only to differences in summer outflow between the alternatives. Across the four phases, mean summer outflow was 0-1% lower than the No Action Alternative, suggesting that negligible impact on the survival of post-larval Delta smelt would result.

The preferred set of covariates identified through extensive model selection did not include any parameters that differed between alternatives (Attachment F.1, *Maunder and Deriso in R Model*). Mean Delta water temperature and Secchi depth were the selected parameters for the fall period, which correspond to juvenile survival in the MDR model. Although hydrological differences between the alternatives would potentially impact these variables, the relationships between flow, temperature and turbidity are complex, and were not able to be modeled for this exercise. As such, juvenile Delta smelt survival under Alternative 2 was the same as under the No Action Alternative.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the fall showed significant relationships for two taxa; *E. affinis* adults and mysids. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 2, when compared to the No Action Alternative, for *E. affinis* there was no expected change in CPUE across all water types and phases of Alternative 2. However, the expected CPUE for *E. affinis* during the fall was very low (1–3 individuals per cubic meter) and unlikely to impact Delta smelt juveniles. Mysids had the largest expected increase of 14% during the dry water year type for the without TUCP Systemwide VA phase. Mysid CPUE was not expected to change for the wet and below water year types across all phases; the dry water year type for the phases without VAs and the Delta VA phase; and the critically dry water year type across all phases (Attachment J.3, *Zooplankton-Delta Outflow*

Analysis). The CalSim 3 simulated average Delta outflows under Alternative 2 during the fall were generally only slightly (<5%) different from the No Action Alternative for all phases (Table O-206 through Table O-209). As a result, zooplankton CPUE was generally similar to the No Action Alternative.

Summary

Alternative 2 relative to the No Action Alternative is expected to have a negligible to minor impacts on juvenile Delta smelt due to differences in flow. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the summer and fall, which is expected to have negligible impacts on juvenile Delta smelt. The results of the HSI analyses suggest that Alternative 2 depending on water year type and the application of a water temperature threshold in comparison to the No Action Alternative would likely have negligible to minor adverse and beneficial impacts on juvenile Delta smelt summer and fall habitat. Results from the revised Maunder and Deriso life cycle model suggest negligible impact on the survival of post-larval Delta smelt under all phases of Alternative 2. Under Alternative 2, CPUE of Delta smelt prey species was not related to outflow in the summer and tis expected to be similar to the No Action Alternative during the fall.

Potential Changes to Entrainment of Delta Smelt

Alternative 2 relative to the No Action Alternative is expected to affect the entrainment of juvenile Delta smelt due to differences in flow. Entrainment varies annually and depends on a combination of hydrology, turbidity, and export rates (see Smith et al. 2021). Historic salvage shows juvenile Delta smelt are entrained in the Delta Fish Collection Facilities, however in more recent years fewer fish have been entrained likely due to a combination of changes to operations and the continued decline of the Delta smelt population. While the USFWS life cycle model does incorporate entrainment, it was not used to evaluate entrainment of juvenile Delta smelt. Instead, OMR flows were used to evaluate changes between Alternative 2 and the No Action Alternative.

CalSim 3 OMR Values

OMR combined flows ranged from similar to less negative under Alternative 2 when compared to the No Action Alternative from June to November, which would have negligible to positive effects on entrainment of juvenile Delta smelt (Table O-210 through Table O-213). Across all phases, OMR flow was less negative in June, which would have beneficial effects on juvenile Delta smelt entrainment. Across all other months through November, in general OMR flows were similar to the No Action Alternative across all phases, which would have negligible effects on juvenile Delta smelt entrainment.

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible to beneficial impacts on the entrainment of juvenile Delta smelt due to differences in flow. Alternative 2 relative to the No Action Alternative is in general less advers across all phases in June, which would have beneficial impacts on juvenile Delta smelt, and similar to the No Action Alternative from July to November, which is expected to have negligible impact due to differences in flow.

O.5.13 Longfin Smelt

O.5.13.1 Bay Delta

Adult Migration and Spawning

Longfin smelt are anadromous and spawn in fresh or low-salinity water in the Bay-Delta (Grimaldo et al. 2017), generally at 2 years of age (Moyle 2002). A portion of the population migrate from the ocean into the San Francisco Estuary and move upstream to spawn during late fall through winter, with most spawning occurring from November through April (California Department of Fish and Wildlife 2009a). Spawning locations have been estimated using field observations of gravid females and yolk-sac larvae (Grimaldo et al. 2017, Lewis et al. 2019) and through particle-tracking modeling (Gross et al. 2022) to suggest spawning extends farther seaward than previously thought (Moyle 2002). Based on these studies, longfin smelt appear to spawn in the low-salinity zone where brackish and freshwaters meet (Grimaldo et al. 2017), and in tidal wetlands of south San Francisco Bay and San Pablo Bay when hydrological conditions favor spawning in more seaward regions (Lewis et al. 2020, Grimaldo et al. 2020). These regions include marshes of the Petaluma watershed, Napa-Sonoma watershed, Sacramento-San Joaquin watershed, and Coyote Creek watershed (Lewis et al. 2020, Hobbs et al. 2015).

Potential Changes to Longfin Smelt from Seasonal Operations

Alternative 2 relative to the No Action Alternative is expected to have effects on adult migrating and spawning longfin smelt including X2 position and prey availability.

<u>CalSim 3 Modeled X2 Position</u>

The position of X2 under Alternative 2 was similar to the No Action Alternative (Table O-198 through Table O-201) during the adult longfin smelt migration and spawning period, only varying zero to fourkm from the No Action Alternative, likely having negligible impacts on adult longfin smelt in the fall, winter and spring.

<u>Zooplankton CPUE-Outflow Analysis</u>

Analysis of CPUE with outflow during the fall showed significant relationships for two taxa; *E. affinis* adults and mysids. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 2, when compared to the No Action Alternative, for *E. affinis* there was no expected change in CPUE across all water types and phases of Alternative 2. However, the expected CPUE for *E. affinis* during the fall was very low (1–3 individuals per cubic meter) and unlikely to impact longfin smelt. Mysids had the largest expected increase of 14% during the dry water year type for the without TUCP Systemwide VA phase. Mysid CPUE was not expected to change for the wet and below water year types across all phases; the dry water year type for the phases without VAs and the Delta VA phase; and the critically dry water year type across all phases (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 2 during the fall were generally only slightly (<5%) different from the No Action Alternative for all phases (Table O-206 through Table O-209). As a result, zooplankton CPUE was generally similar to the No Action Alternative.

Analysis of CPUE with outflow during the winter in the LSZ showed significant relationships for five zooplankton taxa; *Daphnia* adults, decapod larvae, *Eurytemora affinis* adults, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 2, when compared to the No Action Alternative, for *Daphnia* adults, there was a 20% expected CPUE increase during the critically dry water year type for the with phases without VAs. There was no expected change in CPUE in the wet, above normal, below normal, and dry water year type for all phases and during the critically dry water year type for the phases with VAs. Results for decapod larvae CPUE were negligible when rounded to the nearest whole integer (values were 0) across all WYT and scenarios. *E. affinis* adults had the largest expected CPUE increase of 2% during the dry water year type for all phases and for the critically dry water year type for the without TUCP, no VA phase. There was no expected change in CPUE in the above normal water year type for the phases without VAs, and the phase with Delta VAs, in the below normal water year type for the no TUCP, Delta VA phase and in the critically dry water year type for the with TUCP Without VA phase, and phases with VAs. For other calanoid copepod adults (*Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), the largest expected CPUE increase of 6% was during the below normal water year type for the phases without VAs and the Systemwide VA phase. There was no expected change in CPUE in the wet water year type for the phases with VAs, in the above normal water year type for the phases without VAs and the Delta VA phase; similarly, CPUE wasn't expected to change in the below normal water year type for the Delta VA phase and in the dry and critically dry water year type for all phases. For other calanoid copepod copepodites (*Acartia* spp., *Acartiella* spp., unidentified calanoids, *Eurytemora affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), there was a 3% expected CPUE increase during the dry water year type for all phases and during the critically dry water year type for the without TUCP Without VA phase. There was no expected change in CPUE in the wet water year type for the phases with VAs, during the above normal water year type for the phase without VAs and the Delta VA phase, and during the critically dry water year type for phases with VAs (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 2 during the winter were generally only slightly (<5%) different from the No Action Alternative except in January of critically dry water year types for the phases without VAs which showed an increase resulting in no to minor increases in zooplankton CPUE (Table O-206 through Table O-209).

Analysis of CPUE with outflow during the spring showed significant relationships for the 5 zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 2, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 20% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 4% during the above normal water year type for the phases without VAs. *E. affinis* adults had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal water year type for the with TUCP Without VA phase. Harpacticoids had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal water year type and the below normal water year type for the phases without VAs. Other calanoid adults had the largest expected CPUE increase of

14% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal and below normal water year type for the with TUCP no VA phase. Other calanoid copepodites had the largest expected CPUE increase of 10% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal and the below normal water year type for the phases without VAs. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflow under Alternative 2 during the spring generally decreased in May for the wet, above normal, and below normal water year types for all phases except the phase with systemwide VAs, when compared to the No Action Alternative. Flows were higher for the phase with systemwide VAs in March and April and higher in March for the phase with Delta VAs. Flows were also higher during the critically dry water year type for all phases except the with TUCP no VA phase (Table O-206 through Table O-209). As a result, zooplankton CPUE showed increases during the critically dry water year type in the spring for all phases except the with TUCP no VA phase and during the below normal, dry and critically dry water year type for the systemwide VA phase.

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on adult longfin smelt migration and spawning due to differences in flow. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to generally minorly change during the fall, winter and increase in the spring depending on Alternative 2 phase and water year type. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the fall, winter and spring which are expected to have a negligible impact on adult longfin smelt migration and spawning.

Potential Changes to Entrainment of Longfin Smelt

Alternative 2 relative to the No Action Alternative is expected to affect the entrainment of adult longfin smelt due to differences in flow. Entrainment varies annually and depends on a combination of hydrology and export rates.

CalSim 3 Modeled X2 Position

Modeling analysis of adult longfin salvage presented in CDFW (2020) predicted increased adult salvage when X2 was near 65 km and when X2 was beyond 75 km. During periods of high outflow adult longfin smelt are less likely to be entrained because the low salinity zone is further away from the Delta, and more individuals may spawn in areas where freshwater flow creates ideal spawning environments. The increase in salvage when X2 was at 65 km is believed to be due to adult longfin staging in Suisun Bay before migrating into the Delta.

The position of X2 under Alternative 2 was similar to the No Action Alternative (O.5-25, O.5-26, O.5-27, O.5-28) during the adult longfin smelt migration and spawning period, only varying 0–4 km from the No Action Alternative.

CalSim 3 Total Exports and OMR Values

An effects analysis of adult longfin smelt entrainment at CVP and SWP facilities found that salvage was increased with fish proximity to the facilities and the magnitude of negative OMR flows caused by the export facilities (CDFW 2020). The analysis noted that this is an additive

effect; salvage only increased when multiple factors (e.g. increased proximity to export facilities, high exports, and highly negative OMR) were considered. The model predicted the magnitude of salvage events increased when total Delta exports increased and when OMR values were more negative than -5000 cfs, however the analysis was not able to identify the underlying mechanisms for the -5000 cfs threshold.

Total exports during the adult longfin smelt migration and spawning period under Alternative 2 were relatively similar to the No Action Alternative for most months but did increase in April for the phases without VAs and decreased in March for the phases with VAs. OMR combined flows were generally similar compared to the No Action Alternative for most months, but were more negative in April without VAs and was less negative in March for phases with VAs (Table O-210 through Table O-213). OMR combined flows for all phases were less negative than the -5000 cfs threshold. Compared to the No Action Alternative, there is likely a minor adverse effect for the phases without VAs and a minor beneficial effect for the phases with VAs.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor adverse to minor beneficial impacts on entrainment of adult longfin smelt during migration and spawning due to differences in flow. Compared to the No Action Alternative, the position of X2 only varied–zero to four km under Alternative 2, likely having a negligible impact on adult longfin smelt. Compared to the No Action Alternative, under Alternative 2, exports were higher and OMR values were more negative in April for the phases without VAs and exports were lower and OMR values were less negative in March for the phases with VAs, likely resulting in a minor adverse impacts for the phases without VAs and a minor beneficial impacts for the phases with VAs.

Eggs and Larvae

In the San Francisco Estuary, most longfin smelt larvae hatch between December and May, and rarely outside of this range (Baxter 1999). Longfin smelt larvae are most abundant in the water column usually from January through April (Bureau of Reclamation 2008). Larval longfin smelt rear in low salinity to brackish water (2–12 ppt; Grimaldo et al. 2017) and in tidal wetlands of San Pablo Bay (Sonoma Creek, Napa River, and Petaluma River) and south San Francisco Bay (Alviso Marsh Complex and salt pond restoration areas) (Hobbs et al. 2015; Lewis et al. 2020). The spatial distribution of these larvae reflects the year-to-year variation in freshwater outflow which affects the geographic location of the low-salinity zone during the winter and spring (Dege and Brown 2004; Grimaldo et al. 2020). During high outflow years, the low salinity zone can extend into San Pablo Bay. Within the low-salinity zone and adjacent waters, larvae have been commonly collected in both littoral (nearshore) and pelagic (offshore) habitats.

Potential Changes to Longfin Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 2 was similar to the No Action Alternative (Table O-198 through Table O-201) during the larval longfin smelt period, only varying zero to four km from the No Action Alternative, likely having negligible impacts on larval longfin smelt in the spring.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the spring showed significant relationships for the five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 2, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 20% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 4% during the above normal water year type for the phases without VAs. *E. affinis* adults had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal water year type for the with TUCP Without VA phase. Harpacticoids had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal water year type and the below normal water year type for the phases without VAs. Other calanoid adults had the largest expected CPUE increase of 14% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal and below normal water year type for the with TUCP no VA phase. Other calanoid copepodites had the largest expected CPUE increase of 10% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal and the below normal water year type for the phases without VAs. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflow under Alternative 2 during the spring generally decreased in May for the wet, above normal, and below normal water year types for all phases except the phase with systemwide VAs, when compared to the No Action Alternative. Flows were higher for the phase with systemwide VAs in March and April and higher in March for the phase with Delta VAs. Flows were also higher during the critically dry water year type for all phases except the with TUCP no VA phase (Table O-206 through Table O-209). As a result, zooplankton CPUE showed increases during the critically dry water year type in the spring for all phases except the with TUCP no VA phase and during the below normal, dry and critically dry water year type for the systemwide VA phase.

Summary

Alternative 2 relative to the No Action Alternative is expected to have both adverse and beneficial impacts on longfin smelt larvae due to differences in flow. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to minorly decrease during the wet year type (-1%) for all phases, and during all water year types except the critically dry water year type for the phases without VAs. CPUE increased during all water year types except for the wet water year type for phase with systemwide VAs and during the dry and critically dry water year type for the phase with Delta VAs. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the spring which are expected to have negligible impacts on larval longfin smelt.

Potential Changes to Entrainment of Longfin Smelt

Alternative 2 relative to the No Action Alternative is expected to have effects on entrainment of longfin smelt larvae due to differences in flow. These possible differences were evaluated using a quantitative model.

Particle Tracking Model (PTM)

Inflow Bins

Depending on inflow conditions, an average of 1 to 16% (SO) or 1 to 13% (NB) of particles injected within the Sacramento River region would be entrained at export facilities under the four phases of Alternative 2, compared to 1 to 16% (SO) and 1 to 13% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 37% (SO) or 38% (NB) lower for Alternative 2 Without TUCP system-wide VA than for the No Action Alternative under "lomed" inflow conditions, to 9% higher than for the No Action Alternative for Alternative 2 Without TUCP system-wide VA (SO) and 8% higher than the No Action Alternative for Alternative 2 Without TUCP Delta VA under "hilo" inflow conditions (NB).

Depending on inflow conditions, an average of 0 to 4% (SO) or 0 to 3% (NB) of particles injected within the Western Delta region would be entrained at export facilities under the four phases of Alternative 2, compared to 0 to 4% (SO) and 0 to 3% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 41% lower than the No Action Alternative for Alternative 2 With TUCP system-wide VA under "lomed" conditions for both SO and NB particles, to 62% higher for Alternative 2 Without TUCP Delta VA under "hihi" conditions (SO) and 98% higher for Alternative 2 Without TUCP Delta VA and Alternative 2 Without TUCP system-wide VA under "hihi" conditions (NB). Note however that under those high flow conditions, the average percentage of particles entrained at exports would remain extremely low (close to 0 for both alternative 2 and the No Action Alternative).

Depending on inflow conditions, an average of 0 to 7% (SO) or 0 to 5% (NB) of particles injected within the Yolo Bypass region would be entrained at export facilities under the four phases of Alternative 2, compared to 0 to 8% (SO) and 0 to 5% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 38% lower for both SO and NB particles for Alternative 2 Without TUCP system-wide VA than for the No Action Alternative under "lomed" inflow conditions, to 15% higher than for the No Action Alternative for Alternative 2 Without TUCP Delta VA (SO) and 16% higher for Alternative 2 Without TUCP system-wide VA (NB) under "hilo" inflow conditions.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of inflow conditions, there was generally a difference between the average percentage of particles entrained under Alternative 4 and under the No Action Alternative (-9 to +2% NB and SO).

OMR bins

Depending on OMR flow conditions, an average of 16 to 81% (SO) or 15 to 79% (NB) of particles injected within the Central Delta region would be entrained at export facilities under the four phases of Alternative 2, compared to 24 to 81% (SO) and 22 to 79% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 31% lower under Alternative 2 Without TUCP Delta VA than under the No Action Alternative for the -2000 OMR bin for both SO and NB particles, to 16% higher under Alternative 2 Without TUCP Delta VA (SO and NB) and Alternative 2 Without TUCP System-wide VA (NB) than under the No Action Alternative for the -3500 OMR bin.

Depending on OMR flow conditions, an average of 17 to 79% (SO) or 16 to 76% (NB) of particles injected within the Mokelumne River region would be entrained at export facilities under the four phases of Alternative 2, compared to 23 to 78% (SO) and 21 to 75% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 26% lower (SO) or 27% lower (NB) under Alternative 2 Without TUCP Delta VA than under the No Action Alternative for the -2000 OMR bin, to 16% higher (both SO and NB) under Alternative 2 Without TUCP Delta VA for the -3500 OMR bin.

Depending on OMR flow conditions, an average of 1 to 16% (SO) or 1 to 13% (NB) of particles injected within the Yolo Bypass region would be entrained at export facilities under the four phases of Alternative 2, compared to 2 to 16% (SO) and 1 to 13 % (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 50% lower (SO) and 51% lower (NB) under Alternative 2 Without TUCP system-wide VA than under the No Action Alternative for the -2000 OMR bin, to 18% higher under Alternative 2 Without TUCP System-wide VA (SO) and 21% higher under Alternative 2 Without TUCP Delta VA (NB) for the -3500 OMR bin.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of OMR flow conditions, there was generally little difference between the average percentage of particles entrained under Alternative 4 and under the No Action Alternative (-3 to +1% NB and SO).

Summary

The percentage of particles entrained at exports were generally similar between surface-oriented particles representative of yolk-sac larval longfin smelt and neutrally buoyant particles representative of >10mm larval longfin smelt. Alternative 2 relative to the No Action Alternative for injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta) is expected to have a mostly similar or beneficial impact on the entrainment of larval longfin smelt, depending on particle origin, inflow grouping, and OMR grouping due to differences in flow.

Juveniles

Juveniles have been detected throughout the San Francisco Estuary and rarely in some Delta tributaries (Merz et al. 2013). Juveniles gradually move seaward as they grow and as water temperatures increase in the late spring and early summer (Rosenfield and Baxter 2007; Tobias and Baxter 2021). Seasonal patterns in abundance and occurrence in the nearshore ocean suggest that the population is at least partially anadromous (Rosenfield and Baxter 2007; Garwood 2017). The detection of longfin smelt within the estuary throughout the year and geochemical analysis of otoliths suggests longfin smelt in the San Francisco Estuary utilize several life history strategies (Lewis et al. 2019).

Potential Changes to Longfin Smelt from Seasonal Operations

Alternative 2 relative to the No Action Alternative is expected to have effects on juvenile longfin smelt including X2 position, abundance, and prey availability. These possible differences were evaluated using several quantitative models.

CalSim 3 X2 Modeled X2 Position

Longfin smelt utilize low salinity zone (LSZ, 0.5–6 psu) habitat for spawning and rearing (Grimaldo et al. 2017, Merz et al. 2013, Hobbs et al. 2010). X2 (the distance of 2 psu salinity isohaline from the Golden Gate Bridge) has been used as a proxy for the LSZ (MacWilliams et al. 2015, Kimmerer et al. 2013, Jassby et al. 1995). The position of X2 responds to CVP and SWP operations, the more freshwater outflow into the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and at the confluence of the Sacramento and San Joaquin rivers (X2 ~ 80-85 km).

The position of X2 under Alternative 2 was similar to the No Action Alternative (Table O-198 through Table O-201) during the juvenile longfin smelt period, only varying 0-4 km from the No Action Alternative, likely having negligible impacts on juvenile longfin smelt in the spring and summer.

Longfin Smelt Abundance–Outflow Analysis

Juvenile longfin smelt abundance as represented by the Fall Midwater Trawl index of abundance is predicted to be similar between each of the phases of Alternative 2 and the No Action Alternative, i.e., plus or minus 5%, depending on the water year type and specific phase of Alternative 2 (Attachment J.1, *Longfin Smelt Outflow*, Table 3). During critically dry water years, Alternative 2 is predicted to result in longfin smelt abundance that is between 1% lower to 4% higher than the No Action Alternative. For all phases of Alternative 2, predicted longfin smelt abundance during wet water years is between 0% to 2% lower than the No Action Alternative.

Zooplankton CPUE-Outflow Analysis

Under Alternative 2, when compared to the No Action Alternative, cladocerans (except *Daphnia*), had the largest expected CPUE increase of 20% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 4% during the above normal water year type for the phases without VAs. *E. affinis* adults had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal water year type for the with TUCP Without VA phase. Harpacticoids had the largest expected increase of 11% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal water year type and the below normal water year type for the phases without VAs. Other calanoid adults had the largest expected CPUE increase of 14% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 3% during the above normal and below normal water year type for the with TUCP no VA phase. Other calanoid copepodites had the largest expected CPUE increase of 10% during the critically dry water year type for the without TUCP Systemwide VA phase and the largest expected CPUE decrease of 2% during the above normal and the below normal water year type for the phases without VAs. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflow under Alternative 2 during the spring generally decreased in May for the wet, above

normal, and below normal water year types for all phases except the phase with systemwide VAs, when compared to the No Action Alternative. Flows were higher for the phase with systemwide VAs in March and April and higher in March for the phase with Delta VAs. Flows were also higher during the critically dry water year type for all phases except the with TUCP no VA phase (Table O-206 through Table O-209). As a result, zooplankton CPUE showed increases during the critically dry water year type in the spring for all phases except the with TUCP no VA phase and during the below normal, dry and critically dry water year type for the systemwide VA phase.

During the summer months (May to August), the zooplankton-outflow analysis showed no significant relationships between outflow and zooplankton CPUE. Several studies have previously found relationships between abundance of zooplankton taxa and outflow during the summer (e.g. Kimmerer 2002b, Kimmerer et al. 2018), while other studies have found mixed effects (Frantzich et al. 2021) or no effects (Sommer et al. 2020) of increased flow on zooplankton abundance. Evaluating possible benefits of increased outflow and flow pulses during summer may be difficult given sampling frequency and the effect size of increases to zooplankton abundances (Brandon et al. 2021).

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor adverse and beneficial impacts on juvenile longfin smelt depending on the phase and water year type due to differences in flow. Juvenile longfin smelt abundance as represented by the Fall Midwater Trawl index of abundance is predicted 1%–3% lower depending on the Alternative 2 phase during wet years compared to the No Action Alternative and 0 to 4% higher depending on the Alternative 2 phase during critically dry years compared to the No Action Alternative. Compared to the No Action Alternative, CPUE of longfin smelt prey species was only minorly (<5%) different except in January of critically dry water year types for the phases without VAs which showed an increase resulting in no to minor increases in in zooplankton CPUE during the winter, and the CPUE is expected to be similar to the No Action Alternative during the fall. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the spring and summer which are expected to have a negligible impact on juvenile longfin smelt.

Potential Changes to Entrainment of Longfin Smelt

Longfin Smelt Outflow Entrainment

The regression from Grimaldo et al. (2009) between April-May juvenile longfin smelt entrainment and Old and Middle River flows was used to assess potential differences in salvage between modeled alternatives. The analysis does not account for changes in operations since the USFWS 2008 and 2009 biological opinions, changes in population size over time, turbidity, juvenile behavior, and geographic shifts in distribution during higher outflow years.

Changes in OMR flows under Alternative 2 compared with the No Action Alternative may have an impact on LFS salvage. Compared to the No Action Alternative, for the with TUCP no VA phase, predicted salvage increases ranged from 29% during the critically dry water year type to 181% during the above normal water year type. For the without TUCP no VA phase, predicted salvage increases ranged from 23% during the critically dry water year type to 181% during the above normal water year type. For the without TUCP Delta VA phase, predicted salvage increases ranged from 8% during the dry water year type to 103% during the wet water year

type. For the without TUCP Systemwide VA phase, predicted salvage ranged from a 4% decrease during the dry water year type to a 98% increase during the wet water year type. Alternative 2 had higher negative mean April-May OMR values across most water year types for all phases. Overall modeling for Alternative 2 suggests that longfin smelt salvage would increase substantially when compared to the No Action Alternative, particularly for the with TUCP no VA, without TUCP no VA, and without TUCP Delta VA phases. Substantial effects were seen during certain water year types for the without TUCP Systemwide VA phase (e.g. wet) but a minor decrease in salvage was seen for the dry water year type. (Attachment I.4, *Longfin Smelt Salvage-OMR Relationship*).

Summary

Alternative 2 relative to the No Action Alternative is expected to have an adverse impact on the entrainment of longfin smelt in all water year types except in a dry water year type under Alternative 2 Without TUCP Systemwide VA which is expected to have a minor beneficial impact due to differences in flow.

O.5.14 Fall-run and Late Fall-run Chinook Salmon ESU

O.5.14.1 Sacramento River

Spawning and Egg/Alevin Incubation

Fall-run Chinook salmon typically spawn in the Sacramento River, primarily between Keswick Dam and RBDD from October through December, with incubation occurring from October through April. Peak spawning time for late fall-run Chinook salmon generally is from January through April (National Marine Fisheries Service 2009a), with incubation typically lasting for approximately seven to 13 months between April and June (Moyle 2002). See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under the four phases of Alternative 2, differences in mean spawning WUA are generally lower than the No Action Alternative across the water year types and phases and are higher in critically dry water years under Alternative 2 With TUCP Without VA (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between the four phases of Alternative 2 and the No Action Alternative is a 1.5% increase in critically dry water years under Alternative 2 With TUCP Without VA. The largest reduction in estimated spawning habitat is a -2.1% decrease in above normal water year types under Alternative 2 Without TUCP Delta VA.

The monthly median values of spawning WUA under the four phases of Alternative 2 are similar to the No Action Alternative in September, October, and December and slightly lower in November (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Estimated spawning WUA median values for all the modeled alternatives are relatively similar in September and October, and slightly lower in November and December. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently highest in

December when compared to other spawning months (Table O-182 through Table O-185). This results in lower spawning WUA results because the fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 3,000 to 6,000 cfs).

Overall, the spawning habitat analysis based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 may have a minor (less than 2.5%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. The results of the spawning habitat analysis based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 may have a minor (less than 2.5%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. Out of the four months of potential fall-run Chinook salmon spawning, September and October have the highest estimated spawning WUA across all alternatives.

Fall-run Chinook Salmon: Redd Dewatering Analysis

Under the four phases of Alternative 2, the fall-run Chinook salmon redd dewatering results show a consistent reduction in redd dewatering potential from wet and above normal water year types to critically dry water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation is expected for fall-run Chinook salmon because their spawning occurs in the fall, with incubation extending into early winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier winters, flow fluctuations are reduced and fewer redds are potentially dewatered. Differences in redd dewatering potential between the four phases of Alternative 2 and the No Action Alternative are variable, with mostly small increases and reductions in all water year types. The largest difference is an increase of 15.6% for critically dry water years under Alternative 2 Without TUCP Without VA The largest reduction is 7.2% for below normal water years under Alternative 2 Without TUCP Without VA. For individual months, redd dewatering for all four phases of Alternative 2 is highest for September spawning (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that redd dewatering potential under the four phases of Alternative 2 would mostly be higher than under the No Action Alternative, but most difference are relatively small, especially on an absolute scale.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 235 for Keswick Dam and Table 236 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 238 for Keswick Dam and Table 239 for RBDD. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during December through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 241 for Keswick Dam and Table 242 for RBDD.

Results for the three analyses are summarized in Table O-74. Table O-74, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 42.1°F to 55°F spawning initiation range analysis, there were zero and one month-water year type combinations (0% and 5.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-74). There were four and one combinations (20.0% to 5.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at Keswick Dam and RBDD. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero and one combinations (0% and 5.0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable results at either location. These results suggest that there would be minor or negligible positive and negative water temperature-related effects of Alternative 2 With TUCP Without VA on fall-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 42.1°F to 55°F spawning initiation range analysis, there were zero and one month-water year type combinations (0% and 5.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-74). There were two and zero combinations (10.0% and 0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were one and zero combinations (5.0% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable conditions at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were no combinations (0%) with favorable or unfavorable results at Keswick Dam and RBDD.. These results suggest that there would be minor or negligible positive and negative water temperature-related effects of Alternative 2 Without TUCP Without VA on fall-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Delta VA** for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0%) with favorable results at Keswick Dam and RBDD (Table O-74). There were five and one combinations (25.0% and 5.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable conditions at Keswick Dam and RBDD. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero and one month-water year type combinations (0% and 5.0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations with unfavorable results at either location. These results suggest that there would be minor positive and negative water temperature-related effects of Alternative 2 Without TUCP Without VA on fall-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 42.1°F to 55°F spawning initiation range analysis, there were zero and one month-water year type combinations (0% and 5.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-74). There were four and one combinations (20.0% to 5.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both Keswick Dam and RBDD. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero and one combinations (0% and 5.0%, respectively) with favorable results at Keswick Dam and RBDD, respectively, and no combinations (0%) with unfavorable results at either location. These results suggest that there would be minor or negligible positive and negative water temperature-related effects of Alternative 2 Without TUCP Without VA on fall-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

Overall, the four phases of Alternative 2 would have negligible positive and negative water temperature-related effects to fall-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River (Table O-74).

Fall-run Chinook Salmon: Sacramento River Pulse Flows

To increase outmigration survival of Chinook salmon, Reclamation would release up to 150 TAF in pulse flow(s) each water year, typically in the spring, to benefit Chinook salmon in the Sacramento River watershed when the pulse does not interfere with the ability to meet temperature objectives or other anticipated operations of the reservoir. Reclamation will schedule this pulse after coordination through the Sacramento River Group and Shasta Operations Team and may include coordinating timing with natural flow events, potential storage management operations and/or pulse flows in tributaries. There may be unintentional adverse impacts of spring pulse flows on redd dewatering from sudden drops in flow. However, redd surveys occur during the pulse flow period and redd dewatering has not been observed.

Fall-run Chinook Salmon: Summary

The differences in seasonal operations in the Sacramento River between Alternative 2 and the No Action Alternative are expected to have minor impacts on fall-run Chinook salmon spawning habitat and incubation in the Sacramento River. Under Alternative 2, changes in flows may result in minor increases or decreases in spawning habitat area, with September and October having the greatest spawning WUA. Fall-run Chinook salmon redd dewatering potential under Alternative 2 is generally slightly higher than under the No Action Alternative, except for appreciable increases in critically dry and below normal water year types for some Alternative 2 phases. There may be redd dewatering following spring pulse flow events, though this has not been observed during redd surveys. Alternative 2 would cause adverse and negligible beneficial water temperature-related impacts to fall-run Chinook salmon spawning and egg/alevin incubation conditions in the Sacramento River.

Late Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under the four phases of Alternative 2, differences in mean spawning WUA are generally lower than or similar to the No Action Alternative across the water year types and phases (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between the four phases of Alternative 2 and the No Action Alternative is a

0.4% increase in critically dry water years under Alternative 2 Without TUCP Systemwide VA. The largest reduction in estimated spawning habitat is a -2.0% decrease in dry water year types under Alternative 2 With TUCP Without VA.

The monthly median values of spawning WUA under the four phases of Alternative 2 are similar to the No Action Alternative throughout the three spawning months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are also relatively similar across all three spawning months. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are highest in February but all three months are above 8,000 cfs (Table O-182 through Table O-185). This results in spawning WUA results that are approximately the same across all three months because the late fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of the spawning habitat analysis based on CalSim 3 simulated flows suggest that the four phases of Alternative 2 may have a minor (less than 2.5%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. The three months of potential late fall-run Chinook salmon spawning have similar estimated spawning WUA across all alternatives.

Late Fall-run Chinook Salmon: Redd Dewatering Analysis

The results for both the No Action Alternative and Alternative 2 show large and consistent variations in percentage of late fall-run Chinook salmon redds dewatered with water year type, varying from high redd dewatering in wet water years to low redd dewatering in critically dry water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation reflects flow conditions for the winter and spring months when late fall-run Chinook salmon spawning and incubation occurs. During wet winters and springs, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. Most differences in mean redd dewatering potential between the four phases of Alternative 2 and the No Action Alternative are small, but some are large, at least in terms of absolute differences. These differences include a 39.2% decrease in redd dewatering under Alternative 2 Without TUCP With Delta VA in critically dry water years and 20.2% and 18.7% increases under Alternative 2 Without TUCP With Systemwide VA in critically dry and dry water years, respectively (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). In terms of absolute differences, the largest difference is a 1.4% increase under Alternative 2 Without TUCP With Systemwide VA. Overall, the results indicate that redd dewatering potential under the four phases of Alternative 2 would be largely similar to results under the No Action Alternative, with consistently small absolute differences.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 267 for Keswick Dam and Table 268 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*,

Table 270 for Keswick Dam and Table 271 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 273 for Keswick Dam and Table 274 for below Clear Creek.

Results for the three analyses are summarized in Table O-75. Table O-75, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 with TUCP Without VA** for the 42.1°F to 55°F spawning initiation range analysis, there were zero and one month-water year type combinations (0% and 5.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and Clear Creek, respectively (Table O-75). There was one and zero combinations (5.0% and 0%, respectively) with unfavorable results at Keswick Dam and below Clear Creek. For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four and five combinations (20.0% and 25.0%, respectively) with favorable results at Keswick Dam and Clear Creek, respectively. There were no combinations (0%) with unfavorable results at both locations. These results suggest that there would be positive water temperature-related effects of Alternative 2 With TUCP Without VA on late fall-run Chinook salmon spawning initiation, egg incubation, and fry emergence, and negligible negative effects to these life stages.
- Under **Alternative 2 Without TUCP Without VA** for the 42.1°F to 55°F spawning initiation range analysis, there were zero and one month-water year type combinations (0% and 5.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and Clear Creek, respectively (Table O-75). There were one and zero combinations (5.0% and 0%, respectively) with unfavorable results at Keswick Dam and Clear Creek, respectively. For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four and five combinations (20.0% and 25.0%, respectively) with favorable results at Keswick Dam and Clear Creek, respectively. There were no combinations (0%) with unfavorable results at both locations. These results suggest that there would be positive water temperature-related effects of Alternative 2 Without TUCP Without VA on late fall-run Chinook salmon spawning initiation, egg incubation, and fry emergence, and negligible negative effects to these life stages.
- Under **Alternative 2 Without TUCP Delta VA** for the 42.1°F to 55°F spawning initiation range analysis, there were zero and one month-water year type combinations (0% and 5.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and Clear Creek, respectively (Table O-75). There were zero combinations (0%) with unfavorable results at Keswick Dam and Clear Creek. For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or

unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four and five combinations (20.0% and 25.0%, respectively) with favorable results at Keswick Dam and Clear Creek, respectively. There were no combinations (0%) with unfavorable results at both locations. These results suggest that there would be positive water temperature-related effects of Alternative 2 Without TUCP Delta VA on late fall-run Chinook salmon spawning initiation, egg incubation, and fry emergence.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 42.1°F to 55°F spawning initiation range analysis, there were zero and two month-water year type combinations (0% and 10.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and Clear Creek, respectively, and no combinations with unfavorable results at both locations (Table O-75). For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four and five combinations (20.0% and 25.0%, respectively) with favorable results at Keswick Dam and Clear Creek, respectively, and no combinations (0%) with unfavorable results at both locations. These results suggest that there would be positive water temperature-related effects of Alternative 2 Without TUCP Systemwide VAs on late fall-run Chinook salmon spawning initiation, egg incubation, and fry emergence.

Overall, the four phases of Alternative 2 would have similar positive water temperature-related effects and negligible negative effects to late fall-run Chinook salmon spawning and egg/incubation in the Sacramento River (Table O-75).

Late Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on spawning behavior and redd dewatering from sudden drops in flow. However, redd surveys occur during the pulse flow period and redd dewatering has not been observed.

Late Fall-run Chinook Salmon: Summary

The differences in seasonal operations in the Sacramento River between Alternative 2 and the No Action Alternative are expected to have similar impacts on late fall-run Chinook salmon spawning habitat and incubation in the Sacramento River. Under Alternative 2, changes in flows may result in negligible increases or decreases in spawning habitat area. Late fall-run Chinook salmon redd dewatering potential under Alternative 2 is largely similar to the No Action Alternative. There may be changes to spawning behavior and redd dewatering with spring pulse flow events, but redd dewatering has not been observed during the pulse flow period. Alternative 2 would cause beneficial and negligible adverse water temperature-related impacts to late fall-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

Juvenile Rearing and Emigration

The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, mostly between January through June. Late fall-run Chinook salmon juveniles typically enter the ocean after seven to 13 months of rearing in freshwater, generally between October and February. See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under the four phases of Alternative 2, mean fry rearing WUA is variable depending on the phase and water year type but have less than a 2% difference compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The only increase in mean fry rearing habitat is under Alternative 2 With TUCP Without VA, with a 0.3% increase in critically dry water year types in comparison the No Action Alternative. The largest reduction in mean fry rearing habitat is under Alternative 2 With TUCP Without VA, with a 1.8% decrease in dry water year types in comparison the No Action Alternative.

The monthly median values of fry rearing WUA under the four phases of Alternative 2 are similar throughout the fry rearing months December through March (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The results during December, January, and March show little variation in the third quartile of the WUA distributions. This occurs because the fry rearing WUA curves peak at the lowest flows encountered in the river (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and Keswick Dam flow releases are frequently low during these months in critically dry water years when Shasta Reservoir is operated to rebuild storage volume (Table O-182 through Table O-185). The first quartile is much wider because a greater range of flows affect the fry rearing WUA values below the median.

The results of the fall-run Chinook salmon fry rearing habitat analysis suggest that the four phases of Alternative 2 in comparison to the No Action Alternative may have a minor (less than 2%) increase and/or decrease in estimated fry rearing habitat across all water year types. The estimated fry rearing habitat are similar from December through March under the four phases of Alternative 2 (less than a 5% difference).

Fall-run Chinook Salmon: Juvenile Rearing Habitat Analysis

Under the four phases of Alternative 2, mean juvenile rearing is variable depending on the phase and water year type but have less than a 3% difference in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat is under Alternative 2 With TUCP Without VA and the No Action Alternative, with a 2.8% increase in critically dry water year types. The largest decrease in estimated juvenile rearing habitat is under Alternative 2 Without TUCP Systemwide VA and the No Action Alternative, with a 0.8% decrease in below normal water year types.

The monthly median value of juvenile rearing WUA under the four phases of Alternative 2 are similar to the No Action Alternative February through June (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). During the juvenile rearing period, the median WUA values steadily decline from the highest median WUA values in March to the lowest median WUA values in July. The lower juvenile rearing WUA values in June result from releases in the summer months above 7,000 cfs (Table O-182 through Table O-185) and estimated peak juvenile rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the fall-run Chinook salmon juvenile rearing habitat analysis suggest that the four phases of Alternative 2 in comparison to the No Action Alternative are expected to have a minor (less than 3%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in the mainstem upper Sacramento River.

Fall-run Chinook Salmon: Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. The four phases of Alternative 2 differ in how juvenile stranding of fall-fun fry varies with water year type (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). All the phases except Alternative 2 Without TUCP Systemwide VA have the highest mean fall-run stranding in wet water years and the lowest stranding in critically dry years. Under Alternative 2 Without TUCP Systemwide VA, the lowest mean stranding is in below normal water years. The four phases of Alternative 2 show similar patterns of variation across the four principal months of fall-run Chinook salmon fry rearing, with the highest stranding in February and the lowest in March (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The means of fall-run Chinook salmon fry stranding under the four phases of Alternative 2 differ inconsistently from the means under the No Action Alternative. However, large reductions in stranding are more prevalent than large increases with reductions of greater than >10% under Alternative 2 Without TUCP Without VA and Alternative 2 Without TUCP Delta VA in critically dry water years and under Alternative 2 Without TUCP Systemwide VA in below normal and above normal water year types. The largest increases in mean stranding of fall-run fry are 8.4% and 6.1% for dry water years under Alternative 2 Without TUCP Delta VA and Alternative 2 Without TUCP Systemwide VA, respectively.

Overall, fall-run juvenile stranding for fry under the four phases of Alternative 2 differs inconsistently in comparison to the No Action Alternative, but reductions are larger and more frequent than increases for all four phases.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 247 for Keswick Dam, Table 248 for Red Bluff Diversion Dam, and Table 249 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 251 for Keswick Dam, Table 251 for Red Bluff Diversion Dam, and Table 253 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 255 for Keswick Dam, Table 256 for Red Bluff Diversion Dam, and Table 257 for Hamilton City.

Results for the three analyses are summarized in Table O-78. Table O-78, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-78). There were zero to three combinations (0% to 15.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations (0%) with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to ten combinations (0% to 50.0%) with favorable results depending on location. There would be no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 With TUCP Without VA on fall-run Chinook salmon juvenile rearing and emigration.
- Under **Alternative 2 Without TUCP Without VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at any location (Table O-78). There were zero to three combinations (0% to 15.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations (0%) with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to nine combinations (0% to 45.0%) with favorable results depending on location. There would be no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 Without TUCP Without VA on fall-run Chinook salmon juvenile rearing and emigration.
- Under **Alternative 2 Without TUCP Delta VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-78). There were zero to three combinations (0% to 15.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations (0%) with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to seven combinations (0% to 35.0%) with favorable results depending on location. There would be no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 Without TUCP Delta VA on fall-run Chinook salmon juvenile rearing and emigration.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-78). There were one to three combinations (5% to 15.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations (0%) with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to seven combinations (0%

to 35.0%) with favorable results depending on location. There would be no combinations (0%) with unfavorable results at all locations. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 Without TUCP Systemwide VAs on fall-run Chinook salmon juvenile rearing and emigration.

Overall, the four phases of Alternative 2 would have similar water temperature-related effects to fall-run Chinook salmon juvenile rearing and outmigration in the Sacramento River. All four phases would have both positive and negative effects on juvenile rearing and outmigration.

Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

Fall-run Chinook Salmon: Summary

Under Alternative 2, differences in seasonal operations in the Sacramento River are largely expected to have minor impacts on fall-run Chinook salmon fry and juvenile rearing habitat and behavior. There would be minor changes in WUA for fall-run Chinook salmon fry rearing in all water year types relative to the No Action Alternative. There would also be a minor to negligible increase in juvenile rearing habitat in all phases of Alternative 2 and all water year types, but similar estimated habitat in the mainstem upper Sacramento River on an average monthly basis. Fry stranding would be both increased and decreased under all phases of Alternative 2, however the increase in stranding was greater and more frequent than the decreases in stranding. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. Under all phases of Alternative 2, fall-run Chinook salmon rearing fry and juveniles would experience more unfavorable water temperature conditions below Keswick Dam and near the RBDD for growth, smoltification, and vulnerability to predators, but more favorable conditions for juveniles with regards to pathogen virulence below RBDD. Alternative 2 is expected to have beneficial and adverse water temperature-related impacts on fall-run Chinook salmon rearing in the Sacramento River.

Late Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under the four phases of Alternative 2, mean fry rearing WUA generally decreases in all water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Under the four phases of Alternative 2, mean fry rearing WUA generally decreases in all water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat is under Alternative 2 Without TUCP Without VA, with a 0.2% increase in above normal water year types in comparison the No Action Alternative. The largest reduction in estimated fry rearing habitat is under Alternative 2 Without TUCP with Systemwide VA, with a 1.7% decrease in below normal water year types in comparison the No Action Alternative.

On a monthly scale, the median value of fry rearing WUA under Alternative 2 is 11% lower than the No Action Alternative in April but similar in March, May, and June (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The median fry rearing WUA values under the modeled alternatives are similar across the months of May and June, and highest in March. The lower fry rearing WUA values in May and June result from releases in the summer months

above 7,000 cfs (Table O-182 through Table O-185) and estimated peak fry rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The monthly median values of fry rearing WUA under the four phases of Alternative 2 is up to 11% lower than the No Action Alternative in April but similar in March, May, and June (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The median fry rearing WUA values under the modeled alternatives are similar across the months of May and June, and highest in March. The lower fry rearing WUA values in May and June result from releases in the summer months above 7,000 cfs (Table O-182 through Table O-185) and estimated peak fry rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the late fall-run Chinook salmon fry rearing habitat analysis suggest that the four phases of Alternative 2 in comparison to the No Action Alternative may have a minor (less than 2%) increase and/or decrease in estimated fry rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in April (11%) in the mainstem upper Sacramento River.

<u>Late Fall-run Chinook Salmon: Fry Stranding Analysis</u>

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. The four phases of Alternative 2 show a similar pattern of variation in how stranding of late fall-fun fry varies with water year type (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). All four phases have the highest mean late fall-run Chinook salmon stranding in wet water years, the next highest in critically dry years, and relatively small differences among the other three water year types. The four phases of Alternative 2 show similar patterns of variation across the four principal months of late fall-run Chinook salmon fry rearing, with the highest stranding in March, the lowest in May, and intermediate stranding in April and June (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The means of late fall-run Chinook salmon fry stranding under the four phases of Alternative 2 are consistently lower than those under the No Action Alternative in wet through dry water year types, but are consistently higher, and generally much higher, in critically dry water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The largest reductions in stranding are 20.1% and 31.4% for above normal and below normal water year types, respectively, under Alternative 2 Without TUCP Systemwide VA. The largest increases, ranging from 30.2% to 41.4%, occur in critically dry water years under Alternative 2 Without TUCP Without VA, Alternative 2 Without TUCP Delta VA, and Alternative 2 Without TUCP Systemwide VA.

Overall, changes in late fall-run Chinook salmon juvenile stranding for fry under the four phases of Alternative 2 versus the No Action Alternative differ greatly between critically dry water years and the other water year types. In critically dry water years, stranding for three of the four phases is much higher than under the No Action Alternative, while in the other water year types stranding is consistently lower for all four phases of Alternative 2 as compared to the No Action Alternative.

Late Fall-run Chinook Salmon: Juvenile Rearing Habitat Analyses

Mean juvenile rearing WUA under the four phases of Alternative 2 in comparison to the No Action Alternative, constitute both increase and reductions depending on the phase and water year type, but are below a 3% difference (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat is under Alternative 2 With TUCP Without VA and the No Action Alternative, with a 2.8% increase in critically dry water year types. The largest reduction in estimated juvenile rearing habitat is under Alternative 2 With TUCP Without VA and the No Action Alternative, with a 0.6% decrease in below normal water year types.

The monthly median values of juvenile rearing WUA under the four phases of Alternative 2 are similar to the No Action Alternative May through September (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under the modeled alternatives gradually decrease from May until the lowest estimated values in July. The highest median WUA values occur in September across all alternatives. The lower juvenile rearing WUA values in June and July result from releases in the summer months above 7,000 cfs (Table O-182 through Table O-185) and estimated peak juvenile rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the fall-run Chinook salmon juvenile rearing habitat analysis suggest that the four phases of Alternative 2 in comparison to the No Action Alternative may have a minor (less than 3%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in the mainstem upper Sacramento River.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 279 for Keswick Dam, Table 280 for Red Bluff Diversion Dam, and Table 281 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 283for Keswick Dam, Table 284 for Red Bluff Diversion Dam, and Table 285 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 287 for Keswick Dam, Table 288 for Red Bluff Diversion Dam, and Table 289 for Hamilton City.

Results for the three analyses are summarized in Table O-77. Table O-77, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to two month-water year type combinations (0% to 3.6% of total combinations during the period) with favorable results depending on

location (Table O-77). There were one to three combinations (1.8% to 5.5%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to 14 combinations (0% to 25.5%) with favorable results depending on location. There were no combinations (0%with unfavorable results at each location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 With TUCP Without VA on late fall-run Chinook salmon juvenile rearing and emigration.

- Under **Alternative 2 Without TUCP Without VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to two month-water year type combinations (0% to 3.6% of total combinations during the period) with favorable results depending on location (Table O-77). There were one to five combinations (1.8% to 9.1%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to 14 combinations (0% to 25.5%) with favorable results depending on location. There were zero combinations (0%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 Without TUCP Without VA on late fall-run Chinook salmon juvenile rearing and emigration.
- Under **Alternative 2 Without TUCP Delta VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were one to four month-water year type combinations (1.8% to 7.3% of total combinations during the period) with favorable results depending on location (Table O-77). There were one to three combinations (1.8% to 5.5%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to 11 combinations (0% to 20.0%) with favorable results depending on location. There were zero and one combinations (0% to 1.8%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 Without TUCP Delta VA on late fall-run Chinook salmon juvenile rearing and emigration.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to three month-water year type combinations (0% to 5.5% of total combinations during the period) with favorable results depending on location (Table O-77). There were two to three combinations (3.6% to 5.5%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to 11 combinations (0% to 20.0%) with favorable results depending on location. There were zero to one combinations (0% to 1.8%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 2 Without TUCP Systemwide VAs on late fall-run Chinook salmon juvenile rearing and emigration.

Overall, the four phases of Alternative 2 would have similar water temperature-related effects to fall-run Chinook salmon juvenile rearing and outmigration in the Sacramento River. All four phases would have both positive and negative water temperature-related effects on juvenile rearing and outmigration (Table O-77).

Late Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

Late Fall-run Chinook Salmon: Summary

Under Alternative 2, differences in seasonal operations in the Sacramento River are largely expected to have minor impacts on late fall-run Chinook salmon fry and juvenile rearing habitat and behavior. There would be minor changes (both increases and decreases) in WUA for late fall-run Chinook salmon fry rearing in all water year types relative to the No Action Alternative. Changes in late fall-run Chinook salmon fry stranding would be minor, both increases and decreases under all phases of Alternative 2 under all water year types. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. Late fall-run Chinook salmon rearing fry and juveniles would experience minor changes in favorable and unfavorable water temperature conditions below Keswick Dam and near the RBDD for growth, smoltification, and vulnerability to predators, and more favorable conditions protecting them from virulent pathogens. Alternative 2 is expected to have beneficial and adverse water temperature-related impacts on late fall-run Chinook salmon rearing in the Sacramento River.

Adult Upstream Migration and Holding

Fall-run Chinook salmon migrate upstream past RBDD on the Sacramento River from July to December, and late fall-run Chinook salmon migrate upstream past RBDD from October through December (National Marine Fisheries Service 2009a). Like spring-run, adult late fall-run Chinook salmon typically hold in the river for 1 month to 3 months before spawning, while fall-run Chinook salmon generally spawn shortly after entering freshwater. See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

- **Alternative 2 With TUCP Without VA:** During the October through December period of adult fall-run and late fall-run Chinook salmon upstream migration and holding, the mean monthly flows under Alternative 2 With TUCP with VA at Sacramento River below Red Bluff Diversion Dam, Keswick Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative with the greatest increase in November (15%) at Keswick Dam and Wilkins Slough during critically dry years (Table O-182, Table O-186, Table O-190, Table O-194).

- **Alternative 2 Without TUCP Without VA:** During the October through December period of adult fall-run and late fall-run Chinook salmon upstream migration and holding, the mean monthly flows under Alternative 2 Without TUCP Without VA at Sacramento River below Red Bluff Diversion Dam, Keswick Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative with the greatest increase in November (15%) at Keswick Dam and Wilkins Slough during critically dry years (Table O-182, Table O-186, Table O-190, Table O-194).
- **Alternative 2 Without TUCP Delta VA:** During the October through December period of adult fall-run and late fall-run Chinook salmon upstream migration and holding, the mean monthly flows under Alternative 2 Without TUCP with Delta VA at Sacramento River below Red Bluff Diversion Dam, Keswick Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative with the greatest increase in November (12-15%) at all locations during critically dry years (Table O-182, Table O-186, Table O-190, Table O-194).
- **Alternative 2 Without TUCP Systemwide VA:** During the October through December period of adult fall-run and late fall-run Chinook salmon upstream migration and holding, the mean monthly flows under Alternative 2 Without TUCP Systemwide VA at Sacramento River below Red Bluff Diversion Dam, Keswick Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative with the greatest increase in November (12%) at Keswick Dam during critically dry years (Table O-182, Table O-186, Table O-190, Table O-194).

Overall, the four phases of Alternative 2 would have similar flows compared to the No Action Alternative. Flows at Hamilton City and Wilkins Slough are sufficient to allow passage and holding for all four phases during all water year types. The average monthly flows across all water year types under all phases of Alternative 2 between June and December would be greater than 5,000 cfs at Wilkins Slough, greater than 6,200 cfs at Hamilton City, greater than 6,700 cfs at RBDD, and greater than 5,900 cfs at Keswick Dam (Tables O-182 through O-197). Flows at in the Sacramento River under all phases of Alternative 2 would be high enough (> 3,250 cfs) to allow upstream passage.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 227 for Keswick Dam, Table 228 for Red Bluff Diversion Dam, and Table 229 for Hamilton City. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 231 for Keswick Dam, Table 232 for Red Bluff Diversion Dam, and Table 233 for Hamilton City.

Results are summarized in Table O-78. Table O-78, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 37.9°F to 68°F successful adult migration range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at each location (Table O-78). There were zero to one combinations (0% to 3.3%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there were zero to four combinations (0% to 16.7%) with favorable results and no combinations (0%) with unfavorable results depending on location. These results suggest that there would be positive effects of Alternative 2 With TUCP Without VA on water temperature conditions for fall-run Chinook salmon adult migrants in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 37.9°F to 68°F successful adult migration range analysis, there were zero to one month-water year type combinations (0% to 3.3% of total combinations during the period) with favorable results depending on location (Table O-78). There were zero and one combinations (0% to 3.3%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there were one to four combinations (0% to 13.3%) with favorable results and zero combinations (0%) with unfavorable results depending on location. These results suggest that there would be positive effects of Alternative 2 Without TUCP Without VA on water temperature conditions for fall-run Chinook salmon adult migrants in the Sacramento River.
- Under **Alternative 2 Without TUCP Delta VA** for the 37.9°F to 68°F successful adult migration range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-78). There were zero and one combinations (0% to 3.3%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there were zero to four combinations (0% to 16.7%) with favorable results and zero and one combinations (0% to 3.3%) with unfavorable results depending on location. These results suggest that there would be positive effects of Alternative 2 Without TUCP Delta VA on water temperature conditions for fall-run Chinook salmon adult migrants in the Sacramento River.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 37.9°F to 68°F successful adult migration range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-78). There were 0 to 1 combinations (0% to 3.3%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there were zero to four combinations (0% to 13.3%) with favorable results and zero and one combinations (0% to 3.3%) with unfavorable results depending on location. These results suggest that there would be positive effects of Alternative 2 Without TUCP Delta VA on water temperature conditions for fall-run Chinook salmon adult migrants in the Sacramento River.

Overall, the four phases of Alternative 2 would have similar water temperature-related effects to fall-run Chinook salmon adult migration and holding in the Sacramento River. All four phases would have positive effects and negligible negative effects on adult migration and holding (Table O-78).

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 259 for Keswick Dam, Table 260 for Red Bluff Diversion Dam, and Table 261 for Hamilton City. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 262 for Keswick Dam, Table 263 for Red Bluff Diversion Dam, and Table 264 for Hamilton City.

Results are summarized in Table O-79. Table O-79, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 37.9°F to 68°F successful adult migration range analysis, there were zero month-water year type combinations (0% to 2.5% of total combinations during the period) with favorable results depending on location (Table O-79). There were no combinations (0%) with unfavorable results at all locations. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to two combinations (0% to 10.0%) with favorable results and no combinations (0%) with unfavorable results depending on location. These results suggest that there would be positive effects of Alternative 2 With TUCP Without VA on water temperature conditions for late fall-run Chinook salmon adult migrants in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 37.9°F to 68°F successful adult migration range analysis, there were zero to one month-water year type combinations (0% to 2.5% of total combinations during the period) with favorable results depending on location (Table O-79). There were zero and one combinations (0% to 2.5%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there would be one to three combinations (2.5% to 7.5%) with favorable results and zero combinations (0%)with unfavorable results depending on location. These results suggest that there would be negligible effects of Alternative 2 Without TUCP Without VA on water temperature conditions for late fall-run Chinook salmon adult migrants in the Sacramento River.
- Under **Alternative 2 Without TUCP Delta VA** for the 37.9°F to 68°F successful adult migration range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-79). There were zero and one combinations (0% to 2.5%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to two combinations (0% to 5.0%) with favorable results and zero and one combinations (0% to 2.5%) with unfavorable results depending on location. These results suggest that there would be negligible effects of Alternative 2 Without TUCP Delta VA on water temperature conditions for late fall-run Chinook salmon adult migrants in the Sacramento River.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 37.9°F to 68°F successful adult migration range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all locations (Table O-79). There were zero and one combinations (0% to 2.5%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to two combinations (0% to 5.0%) with favorable results and zero and one combinations (0% to 2.5%) with unfavorable results depending on location. These results suggest that there would be negligible effects of Alternative 2 Without TUCP Systemwide VAs on water temperature conditions for late fall-run Chinook salmon adult migration and holding in the Sacramento River.

Overall, three of the four phases of Alternative 2 would have similar small or negligible water temperature-related effects on late fall-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River (Table O-79).

Sacramento River Pulse Flows

Fall-run and late fall-run adult migration is outside the spring pulse flow period.

Summary

Under all phases of Alternative 2, differences in seasonal operations in the Sacramento River are largely expected to have similar impacts caused by flows and water temperature conditions on fall-run Chinook salmon and late fall-run Chinook salmon adult migration and holding compared to the No Action Alternative. There would be a beneficial and negligible adverse water temperature-related effects under all phases of Alternative 2 on both fall-run and late fall-run Chinook salmon.

O.5.14.2 Clear Creek

Spawning and Egg Incubation

Fall-run Chinook salmon typically spawn in Clear Creek from late September through early December, (Earley et al. 2013). Fall-run typically emerge from the gravel in December through March. Timing of peak late-fall spawning in the Sacramento River, January through April, was used as a proxy for Clear Creek. Late fall-run Chinook salmon incubation and emergence is estimated to occur from March through June.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under the four phases of Alternative 2, mean spawning WUA increases in all water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The greatest increase in estimated spawning habitat is a 6.9% increase in critically dry water year types under Alternative 2 Without TUCP with Delta VA. There are no anticipated reductions in mean spawning WUA under the four phases of Alternative 2 in comparison to the No Action Alternative.

The mean values of spawning WUA by month are higher in November and December and lower in October under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the three months, December is expected to have the highest spawning WUA values under Alternative 2.

The spawning habitat analysis suggests that the four phases of Alternative 2 may have a beneficial effect (1.7-6.9% increase) in fall-run Chinook salmon estimated spawning habitat in Clear Creek across water year types when compared to the No Action Alternative.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 237 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 240 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during December through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 243 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-80. Table O-80, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-80). For the 59.9°F pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero (0%) combinations with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on fall-run Chinook salmon spawning and egg incubation in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-80).

Overall, the four phases of Alternative 2 would have similar negligible effects on water temperature conditions for fall-run Chinook salmon spawning and egg incubation in Clear Creek (Table O-80), relative to the No Action Alternative.

Fall-run Chinook Salmon: Summary

Differences in seasonal operations in Clear Creek between the four phases of Alternative 2 and the No Action Alternative are expected to have a beneficial impact with a potential 1.7-6.9% WUA increase for fall-run Chinook salmon estimated spawning habitat in Clear Creek across water year types when compared to the No Action Alternative. Differences in water temperature between the four phases of Alternative 2 and the No Action Alternative are expected to have similar negligible impacts on spawning and egg incubation.

Late Fall-run Chinook Salmon: CalSim 3 Flows

Under the four phases of Alternative 2, average flows released below Whiskeytown Dam would be reduced from in February and June and higher in January and March through May (Table O-218 through Table O-221) when compared to the No Action Alternative. The largest flow decrease under Alternative 2, compared to the No Action Alternative, occur in June of all water year types, and in February in wet, above normal, and below normal water years. There would be mostly flow increases under Alternative 2 compared to the No Action Alternative that occur in January, March, and May are in all water year types. Under Alternative 2 compared to the No Action Alternative, the average of all water year flow simulations project flow decreases June through October and February and increases November through January and March through May.

Using peak spawning flows of 300-350 cfs from the fall-run WUA curves as a proxy for potential late-fall-run spawning habitat changes under Alternative 2 suggest that despite some decreases, when averaged across all water year types, flows would remain near peak spawning flows of 300 cfs from January (301 cfs) through March (280 cfs). Under Alternative 2, there would be an increase in spawning habitat available for late fall-run Chinook salmon as a result of flows in Clear Creek.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 269 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 272 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 275 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-81. Table O-81, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2** for the 42.1°F to 55°F range for spawning initiation temperature analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results below Whiskeytown Dam (Table O-81). For the 59.9°F pathogen virulence threshold, there were no month-water year type combinations (0%) with favorable or unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were no month-water year type combinations (0%) with favorable or unfavorable results below Whiskeytown Dam.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-81).

Overall, the four phases of Alternative 2 would have similar negligible effects on water temperature conditions for fall-run Chinook salmon spawning and egg incubation in Clear Creek (Table O-81).

Late Fall-run Chinook Salmon: Summary

During the late-fall Chinook salmon spawning and egg incubation periods (January through June), the mean monthly flows under the four phases of Alternative 2 would generally have an increase in January, March, April and May, but moderate to substantial decrease in June and February when averaged across all water year types. This would result in substantial beneficial impacts to late fall-run Chinook salmon for the majority of the spawning and incubation period, but there would be substantial adverse impacts for a portion of the life stage as well. Water temperature results suggest that there would be negligible water temperature-related effects of all phases of Alternative 2 on late fall-run Chinook salmon spawning and egg incubation in Clear Creek.

Juvenile Rearing and Emigration

The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, mostly between January through June. Late fall-run Chinook salmon juveniles typically enter the ocean after seven to 13 months of rearing in freshwater, generally between October and February (Moyle 2002).

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under the four phases of Alternative 2, mean fry rearing WUA decreases in all water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean fry rearing WUA under the four phases of Alternative 2 in comparison to the No Action Alternative. The greatest reduction in estimated fry rearing habitat is a 2.3% decrease in dry water year types under all four phases of Alternative 2.

The mean values of fry rearing WUA by month are slightly lower under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The four fry rearing months are expected to have similar fry rearing WUA values.

The results of the fry rearing habitat analysis indicate that the four phases of Alternative 2 in comparison to the No Action Alternative may have an adverse effect (less than 3% decrease) in estimated fall-run Chinook salmon fry rearing habitat across all water year types in Clear Creek.

Fall-run Chinook Salmon: Juvenile Rearing Habitat Analyses

Under the four phases of Alternative 2, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under the four phases of Alternative 2 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between the four phases Alternative 2 and the No Action Alternative is a 11.3% decrease in critically dry water year types under Alternative 2 Without TUCP Without VA. On average across all water year types, there is a 4.1 to 4.8% reduction in estimated juvenile rearing habitat under the four phases of Alternative 2.

The mean values of juvenile rearing WUA by month are lower June through September and higher in May under Alternative 2 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the five months, May and June are expected to have the highest juvenile rearing WUA values.

The results of the juvenile rearing habitat analyses indicate that the four phases of Alternative 2 in comparison to the No Action Alternative may have a minor adverse impact (4.1-4.8% decrease) in fall-run Chinook salmon juvenile rearing habitat across all water year types.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 250 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 254 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 258 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-82. Table O-82, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-82). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F juvenile pathogen virulence threshold, there

were no month-water year type combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VA** were identical to those for Alternative 2 Without TUCP Without VA (Table O-82).

Overall, all four phases of Alternative 2 would have similar negligible effects on water temperature conditions for fall-run Chinook salmon juvenile rearing and emigration in Clear Creek (Table O-82).

Fall-run Chinook Salmon: Summary

Differences in seasonal operations in Clear Creek between the four phases of Alternative 2 and the No Action Alternative may a minor adverse impact in estimated fall-run Chinook salmon rearing habitat across all water year types in Clear Creek when compared to the No Action Alternative. Differences in water temperature between the four phases of Alternative 2 and the No Action Alternative are expected to have negligible impacts on fall-run Chinook salmon juvenile rearing and emigration.

Late Fall-run Chinook Salmon: CalSim 3 Flows

Under the four phases of Alternative 2 average flows released below Whiskeytown Dam would be reduced from June through October and higher November through January and March through May in most water year types (Table O-218 through Table O-221) when compared to the No Action Alternative. The largest decrease under Alternative 2 compared to the No Action Alternative occur in June through August of all water year types, except critically dry year types when it would occur in June and September. The largest increases under Alternative 2 compared to the No Action Alternative occur in December, January, March, and May all water year types, except critically dry year types when it would occur in January, February, and May. Under Alternative 2 compared to the No Action Alternative, the average of all water year flow simulations project flow decreases June through October and February and increases November through January and March through May.

Using the fall-run Chinook salmon WUA curves as a proxy, optimal flows for maximum late fall-run Chinook salmon juvenile rearing habitat is 300-400 cfs. Under Alternative 2 With TUCP Without VA from March through September during juvenile rearing periods for late fall-run Chinook salmon, flows are expected to be higher than under the No Action Alternative by up to 36% for averaged flows by month across water year types, increasing available habitat. Flows are expected to be decreased June through October, up to 31% lower by average monthly flow across water year types. Results are very similar under all phases of Alternative 2. There would be both a decrease and an increase in juvenile and fry rearing habitat available for late fall-run Chinook salmon as a result of flows in Clear Creek.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation

vulnerability during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 282 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 286 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 290 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-83. Table O-83, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-83). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F juvenile pathogen virulence threshold, there were no month-water year type combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on late fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VA** were identical to those for Alternative 2 Without TUCP Without VA (Table O-83).

Overall, all 4 phases of Alternative 2 would have similar negligible effects on water temperature conditions for late fall-run Chinook salmon juvenile rearing and emigration in Clear Creek (Table O-83).

<u>Late Fall-run Chinook Salmon: Summary</u>

The change in seasonal operations in Clear Creek between all phases of Alternative 2 and the No Action Alternative is expected to have both adverse impacts and beneficial impacts to late fall-run Chinook salmon juvenile rearing and emigration. Under Alternative 2, changes in flows in Clear Creek in June through October would result in substantial adverse impacts to rearing and emigrating juveniles, but flows in November through May would result in moderate to substantial beneficial impacts to rearing and emigrating juveniles. All phases of Alternative 2 would have similar negligible effects on water temperature conditions for late fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Adult Upstream Migration and Holding

Fall-run Chinook salmon may arrive at Clear Creek before spawning from July through early December. Adult late fall-run Chinook salmon migrate and arrive slightly later and do not need to hold and mature before spawning from November into January.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: CalSim 3 Flows

Under the four phases of Alternative 2 average flows released below Whiskeytown Dam would generally be lower June through October and higher November through January and March through May in most water year types simulated (Table O-218 through Table O-221) when compared to the No Action Alternative. The largest decrease under Alternative 2 compared to the No Action Alternative occur in June through August of all water year types, except critically dry year types when it would occur in June and September. The largest increases under Alternative 2 compared to the No Action Alternative occur in December, January, March, and May all water year types, except critically dry year types when it would occur in January, February, and May. Under Alternative 2 compared to the No Action Alternative, the average of all water year flow simulations project flow decreases June through October and February, and increases November through January and March through May.

- **Alternative 2 With TUCP Without VA:** During the fall and late-fall Chinook salmon migration and holding period (July through December), the mean monthly flows under Alternative 2 With TUCP Without VA would be slightly to significant lower during the first half with an average reduction of 25% during July, 20% in August, 10% in September, and 13% in October. Alternatively, the flows would be higher during November (13% average) and December (31% average increase) providing a moderately beneficial impact.
- **Alternative 2 Without TUCP Without VA:** During the fall and late-fall Chinook salmon migration and holding period (July through December), the mean predicted monthly flows under Alternative 2 Without TUCP Without VA are very similar to that of Alternative 2 With TUCP Without VA.
- **Alternative 2 Without TUCP Delta VA:** During the fall and late-fall Chinook salmon migration and holding period (July through December), the mean predicted monthly flows under Alternative 2 Without TUCP Without VA are very similar to that of Alternative 2 With TUCP Without VA.
- **Alternative 2 Without TUCP Systemwide VA:** During the fall and late-fall Chinook salmon migration and holding period (July through December), the mean predicted monthly flows under Alternative 2 Without TUCP Without VA are very similar to that of Alternative 2 With TUCP Without VA.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 230 for Clear Creek below

Whiskeytown Dam. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 234 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-84. Table O-84, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 37.9°F to 68°F successful adult migration range, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-84). For the 59.9°F adult pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be no effect of Alternative 2 With TUCP Without VA on fall-run Chinook salmon adult upstream migration and holding in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-84).

Overall, the four phases of Alternative 2 would have no effect on water temperature conditions for fall-run Chinook salmon adult upstream migration and holding in Clear Creek (Table O-84).

<u>Fall-run Chinook Salmon: Summary</u>

There may both adverse and beneficial impacts of seasonal operations in Clear Creek on fall-run Chinook salmon adult upstream migration and holding based on analyses of simulated flows and water temperature under Alternative 2 in comparison to the No Action Alternative. Under Alternative 2 compared to the No Action Alternative, the average of all water year flow simulations project flow decreases June through October and February, and increases November through January. Water temperature results suggest that there would be no impact of Alternative 2 on fall-run Chinook salmon adult upstream migration and holding and pathogen virulence in Clear Creek below Whiskeytown Dam.

<u>Late Fall-run Chinook Salmon: CalSim 3 Flows</u>

Results of the CalSim 3 models are discussed in the fall-run section above and are similar under all four phases of Alternative 2. During the period of late fall-run adult migration (November - January), the average flow released below Whiskeytown Dam would be increased by 27% on average across all water year types when compared to the No Action Alternative (Table O-218 through Table O-221). The only exception is in December of a critically dry year there is a negligible 2% reduction in modeled flow. These results suggest there would be an increase in suitable migration and holding habitat available for adult late fall-run Chinook salmon as a result of flows in Clear Creek.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature above the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 262 for Clear Creek below Whiskeytown Dam. Full results of the percent of months with water temperature outside the 59.9°F adult pathogen virulence threshold analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 266 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-85. Table O-85, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 37.9°F to 68°F successful adult migration range, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-85). For the 59.9°F adult pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on late fall-run Chinook salmon adult upstream migration and holding in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-85).

Overall, the four phases of Alternative 2 would have no effect on water temperature conditions for late fall-run Chinook salmon adult upstream migration and holding in Clear Creek (Table O-85).

Late Fall-run Chinook Salmon: Summary

Flows would be increased under all four phases of Alternative 2 during the months of late fall-run Chinook salmon adult migration. The only exception is a negligible decrease of 1% during critically dry years in December. Under the four phases of Alternative 2 there would be no impact on water temperature conditions for late fall-run Chinook salmon adult upstream.

O.5.14.3 Lower American River

Spawning and Egg Incubation

Spawning occurs from about mid-October through early February, with peak spawning from mid-October through December. Fall-run chinook salmon spawning occurs within an 18-mile stretch from Paradise Beach to Nimbus Dam; however, most spawning occurs in the uppermost three miles (California Department of Fish and Wildlife 2012a). Chinook salmon egg and alevin incubation occurs in the lower American River from about mid-October through April. There is high variability from year to year; however, most incubation occurs from about mid-October through February.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Spawning Habitat—Flow Analysis

The American River WUA curve peaks at about 2,000 cfs (Attachment M.3, *American River Weighted Usable Area Analysis*) and flows under Alternative 2 are consistently well above this level in the wetter water years. Under the four phases of Alternative 2, fall-run Chinook salmon mean spawning WUA varies modestly among water year types with no obvious pattern except that the means for each water year type are similar across the four phases (Attachment M.3, *American River Weighted Usable Area Analysis*). The highest means are for above normal water year types and the lowest are for wet water years. Mean spawning WUA is consistently lower under all the phases of Alternative 2 than under the No Action Alternative, but only the reductions for critically dry water year types are large, ranging from 7.8% lower for Alternative 2 Without TUCP Without VA to 5.4% lower for Alternative 2 With TUCP Without VA (Attachment M.3, *American River Weighted Usable Area Analysis*). For all three months of the fall-run spawning season, estimated median spawning WUA under the four phases of Alternative 2 are modestly lower than the medians under the No Action Alternative (Attachment M.3, *American River Weighted Usable Area Analysis*). Median WUA for all alternatives is higher in October than November or December because flows, on average, are lower in October (Table O-226 through Table O-229). The fall-run spawning WUA curve (Attachment M.3, *American River Weighted Usable Area Analysis*) peaks at relatively low flows (below 3,000 cfs).

Overall, mean spawning WUA is consistently lower under all the phases of Alternative 2 than under the No Action Alternative, but only reductions for critically dry water year types are moderately large.

Redd Dewatering

The results of the analysis for redd dewatering potential for lower American River fall-run Chinook salmon indicate that mean redd dewatering potential under the four phases of Alternative 2 is consistently highest in wet water years and generally lowest in critically dry and below normal water years (Attachment M.1, *American River Redd Dewatering Analysis*). The higher redd dewatering potential in wet years likely results from a greater frequency of large flow fluctuations in wet water year types. Redd dewatering is consistently higher under the four phases of Alternative 2 than under the No Action Alternative. The increases are greater than 20% for all four phases of Alternative 2, including in above normal water years for Alternative 2 With TUCP Without VA and Alternative 2 Without TUCP Without VA and in below normal water years for Alternative 2 Without TUCP Delta VA and Alternative 2 Without TUCP Systemwide VA (Attachment M.1, *American River Redd Dewatering Analysis*). The size of some of these differences, which are relative differences rather than absolute difference, may be misleading; absolute differences are generally much smaller for these analyses, ranging from 1.4% to 2.5% for the four increases noted above. For the individual months of fall-run Chinook salmon spawning in the lower American River, median redd dewatering potential increases from spawning in October to that in December, reflecting the somewhat higher flows and likelihood of flow fluctuations over this period (Table O-226 through Table O-229).

Overall, mean redd dewatering is higher under the four phases of Alternative 2 than under the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 42.1°F to 55°F range for spawning initiation during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 63 for Hazel Avenue and Table 64 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult spawning pathogen virulence threshold during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 65 for Hazel Avenue and Table 66 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence during October through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 67 for Hazel Avenue and Table 68 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during October through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 69 for Hazel Avenue and Table 70 for Watt Avenue.

Results for the four analyses are summarized in Table O-86. Table O-86, as described in Section O.4.12.3.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 42.1°F to 55°F range for spawning initiation, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue, (Table O-86). For the 59.9°F pathogen virulence threshold for spawning adults, there was zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue. For the 42.8°F to 56°F range for egg incubation and fry emergence analysis, there were zero and one month-water year type combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and one month-water year type combinations (0.0% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold analysis, there were zero month-water type combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Without VA** for the 42.1°F to 55°F range for spawning initiation, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue (Table O-86). For the 59.9°F pathogen virulence threshold for spawning adults, there were zero combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue. For the 42.8°F to 56°F range for egg incubation and fry emergence analysis, there was one month-water year type combination (3.3%) with favorable results at both Hazel and Watt Avenue. There were zero and one month-water type combinations (0.0% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold analysis, there were zero and one month-water type combinations (0% and 3.3%, respectively) with favorable results at Hazel

Avenue and Watt Avenue, respectively. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

- Under **Alternative 2 Without TUCP Delta VA** for the 42.1°F to 55°F range for spawning initiation, there were zero combinations (0%) with favorable results at both Hazel and Watt Avenue, respectively (Table O-86). There were zero and one combinations (0% and 2.9%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for spawning adults, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue, respectively. For the 42.8°F to 56°F range for egg incubation and fry emergence analysis, there were zero and one month-water year type combinations (0.0% and 3.3%, respectively) with favorable results at both Hazel Avenue and Watt Avenue. Similarly, there were zero and one month-water year type combinations (0.0% and 3.3%, respectively) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 59.9°F fry pathogen virulence threshold analysis, there were zero month-water type combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watts Avenue.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 42.1°F to 55°F range for spawning initiation, there were zero combinations (0%) with favorable results at both Hazel and Watt Avenue (Table O-86). There were zero and one combinations (0% and 2.9%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for spawning adults, there were zero and one month-water year type combinations (0.0% and 2.9%, respectively) with favorable results at both Hazel and Watt Avenue. There were zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 42.8°F to 56°F range for egg incubation and fry emergence analysis, there were zero and one month-water type combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watts Avenue, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 59.9°F fry pathogen virulence threshold analysis, there were zero and one month-water type combinations (0.0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watts Avenue. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

Overall, these results suggest that four Alternative 2 phases would have similar positive (2.9-3.3% favorable) and negative (2.9-3.3% unfavorable) water temperature-related effects on fall-run Chinook salmon spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

<u>Summary</u>

Differences in seasonal operations in the lower American River between the four phases of Alternative 2 and the No Action Alternative potentially have a negative impact on fall-run Chinook salmon habitat, with results for critically dry water year types having the largest decrease in WUA at 5.4% lower for Alternative 2 With TUCP Without VA to 7.8% lower for Alternative 2 Without TUCP Without VA. Similarly, redd dewatering is higher under the four phases of Alternative 2 and a potential significant negative impact could occur the large reductions in dry and critically dry years, including a 35.0% reduction for critically dry water

years under Alternative 2 With TUCP Without VA. The water temperature models suggest that Alternative 2 would have positive and negative water temperature-related effects during the fall-run Chinook salmon spawning and egg incubation and fry rearing periods in lower American River at Hazel Avenue and Watt Avenue.

Juvenile Rearing and Emigration

Chinook salmon fry emergence occurs from January through mid-April, and juvenile rearing extends from January to about mid-July (Williams 2001). Most Chinook salmon out-migrate from the lower American River as fry from December to July; out-migration peaks in February and March (Snider and Titus 2002; Pacific States Marine Fisheries Commission 2014).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling during the periods of juvenile rearing and emigration in the lower American River below Nimbus Dam indicate that the simulated flow releases below Nimbus Dam Alternative 2 compared to the No Action Alternative would generally be similar all months of wet water year types and the most different in critically dry year types (Table O-226 through Table O-229). For Alternative 2 With TUCP Without VA, simulations show there may be an increase in flows in December (31%)and July (6%) while decreases may occur on November (6%),February (10%), March (13%),April (8%), June (8%), August (9%), and September (9%) of critically dry type years; all other year types would be similar or the same as the No Action Alternative most months out of the year. Under all other phases of Alternative 2, simulations show there may be an increase in flows in March, April, and June, with increases in April around 100% while decreases may occur July through February and May of critically dry type years; all other year types would be similar or the same as the No Action Alternative most months out of the year. However, all Alternative 2 phases projected for all water year types show average results may be the same or similar projections of the No Action Alternative.

Similar to below Nimbus Dam, CalSim 3 modeling indicates that simulated flow releases in the lower American River at H street Alternative 2 compared to the No Action Alternative would generally be similar all months of wet water year types and the most different in critically dry year types; in critically dry water year types increases and decreases are generally anticipated nearly year-round (Table O-230 through Table O-233). During implementation of Alternative 2 With TUCP Without VA, simulations show that as below Nimbus Dam there may be an increase in flows in December (31%)and July (6%) resulting in a potentially moderate beneficial effect while decreases may occur June, August through November and February through April of critically dry type years potentially a moderate negative effect. All other year types would be similar or the same as the No Action Alternative during most months out of the year. Similarly, under all other phases of Alternative 2, the simulations show that there may be an increase in flows in March, April, and June while decreases may occur from July through February and May of critically dry type years; all other year types would be similar or the same as the No Action Alternative most months out of the year. However, all Alternative 2 phases projected for all water year types show average results may be the same or similar projections of the No Action Alternative, except the final phase when there is an increase for averaged April projections.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 71 for Hazel Avenue and Table 72 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F upper incipient lethal temperature (UILT) for juveniles during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 73 for Hazel Avenue and Table 74 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 75 for Hazel Avenue and Table 76 for Watt Avenue.

Results for the three analyses are summarized in Table O-87. Table O-87, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.12.3.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability, there were zero and one month-water year type combinations (0% and 4.0%, respectively) with favorable results at both Hazel and Watt Avenue, respectively (Table O-87). There were zero month-water year type combinations (0.0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 75.2°F upper incipient lethal temperature (UILT) for juveniles, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue. month-water year type combination For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration, there were zero month-water year type combinations (0%) with favorable and unfavorable results at Hazel Avenue and Watt Avenue month-water year type combination.
- Under **Alternative 2 Without TUCP Without VA** for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability, there were zero and two month-water year type combinations (0.0% and 8.0%, respectively) with favorable results at Hazel and Watt Avenue, respectively (Table O-87). There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75.2°F upper incipient lethal temperature (UILT) for juveniles, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration, there were zero month-water type combinations (0.0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue.

- Under **Alternative 2 Without TUCP Delta VA** for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability, there were zero water-month combination (0.0%) with favorable and unfavorable results at both Hazel and Watt Avenue (Table O-87). For the 75.2°F upper incipient lethal temperature (UILT) for juveniles, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration, there were zero and one month-water year type combinations (0.0% and 4.0%) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water type combinations (8.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue (Table O-87). For the 75.2°F upper incipient lethal temperature (UILT) for juveniles, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration, there were zero and one month-water type combinations (0.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water type combinations (8.0% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that four Alternative 2 phases would have positive (4% - 8% favorable) and negative (4% - 8% unfavorable) water temperature-related effects on fall-run Chinook salmon juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Differences in seasonal operations in the lower American River between the four phases of Alternative 2 and the No Action Alternative potentially have both negative and beneficial impacts on fall-run Chinook salmon habitat with the largest difference potentially occurring in critically dry years with increased flows in December (24%), January (10%), and July (12%) while decreases may occur in November (13%) and February (10%), March (10%) and April (11%). The water temperature model suggests that Alternative 2 would have beneficial and adverse water temperature-related impacts to fall-run Chinook salmon juvenile rearing and outmigration periods in the lower American River at Hazel Avenue and Watt Avenue.

Adult Upstream Migration and Holding

Adult fall-run Chinook salmon enter the lower American River from about mid-September through January, with peak migration from approximately mid-October through December (Williams 2001).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling during the periods of adult migration and emigration indicate that the simulated flow releases below Nimbus Dam Alternative 2 compared to the No Action Alternative would generally be similar all months of wet water year types except for during critically dry year types (Table O-226 through Table O-229). For Alternative 2 With TUCP Without VA, simulations show there may be an increase in flows in December (24%) and in January (10%), while decreases may occur in September (10%), October (13%), and in November (12%) during critically dry type years. All other year types would be similar as the No Action Alternative most months out of the year. Under all the other phases of Alternative 2, simulations show there may be similar decreases in flows in September through December, during critically dry type years. All other year types would be similar as the No Action Alternative most months out of the year. The largest adverse difference during this time period is Alternative 2 Without TUCP with Delta VA during November with a 24% decrease in flows, a moderate negative impact.

CalSim 3 modeling during periods of adult migration and emigration indicates that simulated flow releases at H street Alternative 2 compared to the No Action Alternative would generally be similar all months of wet water year types and the most different in critically dry year types. For Alternative 2 With TUCP Without VA, simulations show there may be an increase in flows in December (24%) and in January (10%), while decreases may occur in September (10%), October (13%), and in November (12%) during critically dry type years. All other year types would be similar as the No Action Alternative most months out of the year. The largest negative difference during this time period is Alternative 2 Without TUCP with Delta VA during November with a 25% decrease in flows, a moderate negative impact.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 59 for Hazel Avenue and Table 60 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 61 for Hazel Avenue and Table 62 for Watt Avenue.

Results for the two analyses are summarized in Table O-88. Table O-88, as described in Section O.4.13.3.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 37.9°F to 68°F successful migration range for adult fall-run Chinook salmon under, there were three and zero month-water year type combinations (8.6% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-88). There were two and three month-water year type combinations (5.7% and 8.6%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence

threshold for adult migration, there were zero month-water year type combination (0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue.

- Under **Alternative 2 Without TUCP Without VA** for the 37.9°F to 68°F successful migration range for adult fall-run Chinook salmon under, there were three and zero month-water year type combinations (8.6% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-88). There were one and four month-water year type combinations (2.9% and 11.4%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for adult migration, there were zero and one month-water year type combinations (0.0% and 2.9%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Delta VA** for the 37.9°F to 68°F successful migration range for adult fall-run Chinook salmon under, there were three and zero month-water year type combinations (8.6% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-88). There were one and two month-water year type combinations (2.9% and 5.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for adult migration, there were zero month-water year type combinations (0%) with favorable and unfavorable results at Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 37.9°F to 68°F successful migration range for adult fall-run Chinook salmon under, there were four and zero month-water year type combinations (11.4% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-88). There were zero and three month-water year type combinations (0% and 8.6%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for adult migration, there were zero and one month-water year type combinations (0% and 2.9%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

Overall, Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP Systemwide VAs the four phases of Alternative 2 would have similar positive (2.9% - 11.4% favorable) and negative (2.9% - 11.4% unfavorable) water temperature-related effects to fall-run Chinook salmon adult upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Differences in seasonal operations in the lower American River between the four phases of Alternative 2 and the No Action Alternative are expected to have a mixed negative and also impact on upstream migrating fall-run Chinook salmon, average monthly flows at below Nimbus Dam may increase in December and January a beneficial impact, but decreases may occur in September through November during critically dry type years a negative impact. Differences in temperature between the four phases of Alternative 2 and the No Action Alternative are expected to have a beneficial and adverse impact on upstream migrating fall-run Chinook salmon. There

would be increases in favorable and unfavorable conditions for successful migration for successful migration under the four phases of Alternative 2 relative to the No Action Alternative.

O.5.14.4 San Joaquin River

Fall-run Chinook salmon adults migrate upstream through the San Joaquin River past Vernalis between September and November. Juvenile fall-run Chinook salmon migrate downstream past Vernalis primarily January through May. See Section O.1.8.1 for additional information.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Under the four phases of Alternative 2 average flows released at on the San Joaquin River near Vernalis would be similar to the No Action Alternative (Table O-242 through Table O-245). All phases of Alternative 2 have a moderate increase in flows in critically dry water years during September when fall-run adult Chinook salmon are migrating upstream. The remaining months for all phases of Alternative 2 have differences in flows, either as an increase or a decrease, between 0 and ± 3%.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on fall-run Chinook salmon in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

There would be similar impacts to migrating adults and juveniles in the San Joaquin River at Vernalis. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.5.14.5 Bay-Delta

Juvenile Rearing and Emigration

Most fall-run Chinook salmon fry rear in freshwater from December through June, with out-migration as smolts occurring primarily from January through June, with presence in the Delta in December through July. In general, fall-run Chinook salmon fry abundance in the Delta increases following high winter flows. Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. Late fall-run Chinook salmon migrants may be found in the Delta between December and April. See Section O.1.9.1 for additional information.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Differences in hydrology in the Delta under the four phases of Alternative 2 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions.

Zone of Influence

Differences in hydrology under the four phases of Alternative 2 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions.

With incremental decreases in OMR under all four phases of Alternative 2 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under the four phases of Alternative 2 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2, *Zone of Influence*).

Flow into Junctions

Alternative 2 relative to the No Action Alternative is expected to have effects on the flow into the Head of Old River and CVP junctions due to differences in flow routing. These possible differences were evaluated using DSM2-HYDRO outputs. For a detailed description of how flows under the four phases of Alternative 2 may impact the flow at Head of Old River and CVP, see Alternative 2, Sacramento River Winter-run Chinook Salmon ESU (Section O.5.8.2, *Flow into Junctions*).

Under all four phases of Alternative 2 and for most OMR bins except -3,500, the predicted proportion of flow entering the CVP is less than the No Action Alternative, although the predicted difference was negligible (up to ± 0.0467 for Alternative 2 Without TUCP Delta VA). Exceptions include the -2,000 OMR bin, with slightly greater change in predicted proportion of flow into CVP for Alternative 2 With TUCP Without VA (-0.069) or Alternative 2 Without TUCP Without VA (-0.0631) indicating that slightly less flow will be routed into CVP under these conditions compared to the No Action Alternative.

Under all four phases of Alternative 2 and for all OMR bins, the predicted differences in proportion of flow entering the HOR compared to the No Action Alternative are negligible (either positive or negative, but always lower than ± 0.008),

Summary

Alternative 2 relative to the No Action Alternative is expected to influence flow into the Head of Old River and CVP junctions due to differences in seasonal operations. Alternative 2 relative to the No Action Alternative is expected to have negligible impact on flow into HOR while differences at CVP are best described between phases of Alternative 2 with and without VA due to differences in flow: Alternative 2 With TUCP Without VA and without TUCP Without VA are expected to have slightly less flow into CVP at OMR -2,000 and Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA are expected to have negligible impacts on flow into CVP. Impacts of pumping under Alternative 2 relative to the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Fall-run / Late Fall-run Chinook Salmon ESU

Salvage Density

- **Alternative 2 With TUCP Without VAs—Fall-run Chinook Salmon**
    - Predictions from the salvage density model for fall-run Chinook salmon include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through July and all water year types Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for all water year types. Predicted average monthly loss at Banks under Alternative 2 With TUCP Without VAs had a range from 29% higher for critically dry water year types to 78% higher for below normal water year types (Table O-89). Predicted average monthly loss of fall-run Chinook salmon at CVP Jones Pumping Plant for the months of November through August and all water year types Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for below normal, and critically dry water year types. Wet, above normal, and dry water year types had equal or lower predicted salvage at Jones. The range of predicted loss for fall-run Chinook salmon at Jones under Alternative 2 With TUCP Without VAs compared to the No Action Alternative was from 1% lower in above normal water year types to 5% higher for critically dry water year types (Table O-90). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.
- **Alternative 2 With TUCP Without VAs—Late Fall-run Chinook Salmon**
    - Predictions from the salvage density model for late fall-run Chinook salmon include mean monthly total exports. Table O-175 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of late fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through April Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for wet water year types, and predicted loss was equal or lower for all other water year types. Predicted average monthly loss at Banks under Alternative 2 With TUCP Without VAs had a range from 3% lower for below normal water year types to 2% higher for critically dry water year types (Table O-91). Predicted average monthly loss of late fall-run Chinook salmon at CVP Jones Pumping Plant for the months of October through April and all water year types Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for above normal and dry water year types, and predicted loss was lower for wet, below normal, and critically dry water year types. The range of predicted loss for late fall-run Chinook salmon at

Jones under Alternative 2 With TUCP Without VAs compared to the No Action Alternative was from 5% lower in critically dry water year types to 6% higher for above normal water year types (Table O-92). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.

- **Alternative 2 Without TUCP Without VAs—Fall-run Chinook Salmon**
    - Predictions from the salvage density model for fall-run Chinook salmon include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through July and all water year types Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for all water year types. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Without VAs had a range from 21% higher for critically dry water year types to 81% higher for below normal water year types (Table O-89). Predicted average monthly loss of fall-run Chinook salmon at CVP Jones Pumping Plant for the months of November through August and all water year types Alternative 2 Without TUCP Without VAs was less or equal than predicted average monthly loss under the No Action Alternative all water year types except for critically dry water year types. The range of predicted loss for fall-run Chinook salmon at Jones under Alternative 2 Without TUCP Without VAs compared to the No Action Alternative was from 1% lower in above normal water year types to 15% higher for critically dry water year types (Table O-90). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.
- **Alternative 2 Without TUCP Without VAs—Late Fall-run Chinook Salmon**
    - Predictions from the salvage density model for late fall-run Chinook salmon include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of late fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through April and all water year types Alternative 2 Without TUCP Without VAs was equal or lower than predicted average monthly loss under the No Action Alternative for all water year types. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Without VAs had a range from 5% lower for critically dry water year types to 1% lower for wet water year types (Table O-91). Predicted average monthly loss of late fall-run Chinook salmon at CVP Jones Pumping Plant for the months of October through April and all water year types Alternative 2 Without TUCP Without VAs was less or equal than predicted average monthly loss under the No Action Alternative for wet, below normal, and dry water year types, predicted loss

was higher for above normal, and critically dry water year types. The range of predicted loss for late fall-run Chinook salmon at Jones under Alternative 2 Without TUCP Without VAs compared to the No Action Alternative was from 3% lower in below normal water year types to 6% higher for above normal water year types (Table O-92). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.

- **Alternative 2 Without TUCP Delta VAs—Fall-run Chinook Salmon**
    - Predictions from the salvage density model for fall-run Chinook salmon include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through July and all water year types Alternative 2 Without TUCP Delta VAs was greater than predicted average monthly loss under the No Action Alternative for all water year types. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Delta VAs had a range from 21% higher for critically dry water year types to 66% higher for below normal water year types (Table O-89). Predicted average monthly loss of fall-run Chinook salmon at CVP Jones Pumping Plant for the months of November through August Alternative 2 Without TUCP Delta VAs was less or equal than predicted average monthly loss under the No Action Alternative for all water year types except for critically dry water year types. The range of predicted loss for fall-run Chinook salmon at Jones under Alternative 2 Without TUCP Delta VAs compared to the No Action Alternative was from 11% lower in dry water year types to 15% higher for critically dry water year types (Table O-90). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.
- **Alternative 2 Without TUCP Delta VAs—Late Fall-run Chinook Salmon**
    - Predictions from the salvage density model for late fall-run Chinook salmon include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of late fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through April and all water year types Alternative 2 Without TUCP Delta VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Delta VAs had a range from 8% lower for critically dry water year types to 1% lower for wet water year types (Table O-91). Predicted average monthly loss of late fall-run Chinook salmon at CVP Jones Pumping Plant for the months of October through April Alternative 2 Without TUCP Delta VAs was lower than predicted average monthly loss under the No Action Alternative for wet, below normal, and dry water year types, predicted loss was higher for above normal, and critically dry

water year types. The range of predicted loss for late fall-run Chinook salmon at Jones under Alternative 2 Without TUCP Delta VAs compared to the No Action Alternative was from 4% lower in below normal water year types to 7% higher for above normal water year types (Table O-92). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.

- **Alternative 2 Without TUCP Systemwide VAs—Fall-run Chinook Salmon**
    - Predictions from the salvage density model for fall-run Chinook salmon include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through July and all water year types Alternative 2 Without TUCP Systemwide VAs was greater than predicted average monthly loss under the No Action Alternative. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Systemwide VAs had a range from 24% higher for critically dry water year types to 68% higher for below normal water year types (Table O-89). Predicted average monthly loss of fall-run Chinook salmon at CVP Jones Pumping Plant for the months of November through August Alternative 2 Without TUCP Systemwide VAs was less than predicted average monthly loss under the No Action Alternative for all water year types except for critically dry water year types. The range of predicted loss for fall-run Chinook salmon at Jones under Alternative 2 Without TUCP Systemwide VAs compared to the No Action Alternative was from 12% lower in dry water year types to 14% higher for critically dry water year types (Table O-90). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.
- **Alternative 2 Without TUCP Systemwide VAs—Late Fall-run Chinook Salmon**
    - Predictions from the salvage density model for late fall-run Chinook salmon include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative. Predicted average monthly loss of late fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through April and all water year types Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly loss under the No Action Alternative for all water year types. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Systemwide VAs had a range from 8% lower for critically dry water year types to 1% lower for wet water year types (Table O-91). Predicted average monthly loss of late fall-run Chinook salmon at CVP Jones Pumping Plant for the months of October through April Alternative 2 Without TUCP Systemwide VAs was less than predicted average monthly loss under the No Action Alternative for wet, below normal, and dry water year types, predicted loss was higher for above normal and

critically dry water year types. The range of predicted loss for late fall-run Chinook salmon at Jones under Alternative 2 Without TUCP Systemwide VAs compared to the No Action Alternative was from 4% lower in below normal water year types to 7% higher for above normal water year types (Table O-91). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.

Summary

The predicted monthly entrainment of fall-run Chinook salmon at Banks Pumping Plant is expected to be substantially increased under all phases of Alternative 2 compared to the No Action Alternative, causing substantial impacts to fall-run Chinook salmon. The predicted monthly entrainment of fall-run Chinook salmon at the Jones Pumping Plant would be similar to the No Action Alternative except during critically dry water year types, when there would be a predicted moderate increase in entrainment. Late fall-run Chinook salmon entrainment at both Banks and Jones Pumping Plants would be similar under all phases of Alternative 2 compared with the No Action Alternative.

Potential Changes to Through Delta Survival of Fall-run / Late Fall-run Chinook Salmon ESU

Delta Passage Model

The DPM simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River and estimates survival to Chipps Island. For this application, only survival of fish entering the Delta from the Sacramento River are evaluated. The DPM uses available time-series data and values taken from empirical studies or other sources to parameterize model relationships and inform uncertainty, thereby using the greatest amount of data available to dynamically simulate responses of smolt survival to changes in water management. (Attachment I.6, *Delta Passage Model*). The major model functions in the DPM are listed under winter-run Chinook salmon (Section *O.4.8.2*).

Fall-run Chinook Salmon

- Under **Alternative 2 With TUCP Without VA**, in all except critically dry water years, predicted mean survival of fall-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.002. There is not a substantial difference in predicted proportion of fall-run Chinook salmon surviving to Chipps Island between Under Alternative 2 With TUCP Without VA and the No Action Alternative.

- Under **Alternative 2 Without TUCP Without VA**, in all except critically dry water years, predicted mean survival of fall-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative. However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.007. There is not a substantial difference in predicted proportion of fall-run Chinook salmon surviving to Chipps Island between Under Alternative 2 Without TUCP Without VA and the No Action Alternative.

- Under **Alternative 2 Without TUCP Delta VA**, in all except critically dry water years, predicted mean survival of fall-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative. However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.007. There is not a substantial difference in predicted proportion of fall-run Chinook salmon surviving to Chipps Island between Under Alternative 2 Without TUCP Delta VA and the No Action Alternative.

- Under **Alternative 2 Without TUCP Systemwide VA**, in all except wet water years, predicted mean survival of fall-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative. However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.008. There is not a substantial difference in predicted proportion of fall-run Chinook salmon surviving to Chipps Island between Under Alternative 2 Without TUCP Systemwide VA and the No Action Alternative.

Late Fall-run Chinook Salmon

- Under **Alternative 2 With TUCP Without VA**, in all water year types, predicted mean survival of late fall-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted survival to Chipps Island in all water year types less than or equal to ± 0.001. There is not a substantial difference in predicted proportion of late fall-run Chinook salmon surviving to Chipps Island between Under Alternative 2 With TUCP Without VA and the No Action Alternative.

- Under **Alternative 2 Without TUCP Without VA**, in all except below normal and critically dry water years, predicted mean survival of late-fall-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative. The change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.001.

- Under **Alternative 2 Without TUCP Delta VA**, in all except critically dry water years, predicted mean survival of late fall-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative. The change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.002.

- Under **Alternative 2 Without TUCP Systemwide VA**, in all except critically dry water years, predicted mean survival of late-fall-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative. The change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.001.

<u>Summary</u>

There would be negligible differences in through Delta survival of both fall-run and late fall-run Chinook salmon through the Delta to Chipps Island compared to the No Action Alternative.

O.5.14.6 Stanislaus River

Spawning and Egg Incubation

Peak spawning for fall-run Chinook salmon in the Stanislaus River typically occurs in November with roughly 7% of spawning occurring prior to November 1, and 2% prior to October 15. The few redds created during late September and early October are typically in the reach just below Goodwin Dam with spawning typically ending in December.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Spawning Habitat—Flow Analysis

The results for fall-run Chinook salmon under the four phases of Alternative 2 show consistent trends of reduction in mean spawning WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the shape of the fall-run spawning WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show reduced WUA with increased flow, except at the lowest and highest flows (less than about 200 cfs to 500 cfs and greater than about 1,000 cfs, respectively). CalSim 3 mean monthly flows below Goodwin Dam, which is immediately upstream of the WUA study reach, are 200 cfs or above in all water year types, with flow generally increasing from critically dry to wet water years during all months of the October through December fall-run spawning period, except December (Table O-234 through Table O-237). The mean spawning WUA estimates for all the phases of Alternative 2 are little different from those of the No Action Alternative in all water year types, ranging from 2.7% lower in below normal water years under Alternative 2 With TUCP Without VA to 0.6% higher in dry water year types under all phases of Alternative 2 except Alternative 2 With TUCP Without VA (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fall-run spawning period, spawning WUA medians under the four phases of Alternative 2 are lower in October than in November or December because of the higher mean flows in October (Table O-234 through Table O-237). Medians are higher under the four phases of Alternative 2 than under the No Action Alternative in November and December and are about the same in October (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that mean spawning WUA for fall-run Chinook salmon are about the same for the four phases of Alternative 2 and the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 55 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult spawning pathogen virulence threshold during October through January are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 56 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 57 for Orange Blossom Bridge. Full results

of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 58 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-93. Table O-93, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.14.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 42.1°F to 55°F range for spawning initiation there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge (Table O-93). For the 59.9°F adult spawning pathogen virulence threshold there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 59.9°F fry pathogen virulence threshold there were also no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-93).

Overall, the four phases of Alternative 2 would have similar negligible water temperature-related effects to fall-run Chinook salmon spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

Differences in seasonal operations in the Stanislaus River between the four phases of Alternative 2 and the No Action Alternative during spawning and incubation periods potentially have generally similar or beneficial impacts on fall-run Chinook salmon habitat. Spawning habitat area is expected to be generally similar under the four phases of Alternative 2 compared to the No Action Alternative. The water temperature model suggests Alternative 2 would have minor beneficial water temperature-related impacts to fall-run Chinook salmon spawning and egg incubation lower American River at Hazel Avenue and Watt Avenue. There would be similar conditions for growth, smoltification, predation vulnerability and pathogen virulence.

Juvenile Rearing and Emigration

Fall-run juvenile rearing in the Stanislaus River typically occurs from January through May (Stanislaus River Fish Group 2004). Fry migration generally occurs from January through March, followed by smolt migration from April through May (Bureau of Reclamation 2012).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Rearing Habitat—WUA Flow Analysis

The results for fall-run fry rearing WUA under the four phases of Alternative 2 show consistent trends of reduction in mean spawning WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the fall-run fry WUA curves, which show reduced WUA with increased flow, especially in the Orange Blossom Bridge and Riverbank reaches (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which are the longest segments of the study. Mean fry rearing WUAs under the phases of Alternative 2 are higher than under the No Action Alternative in all water year types, ranging from 2.7% higher in above normal water years for all four phases of Alternative 2 to 7.2% higher in critically dry water years for all four phases (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fry rearing period, fry rearing is higher under the four phases of Alternative 2 than under the No Action Alternative in all four months (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The differences are especially large for February.

The results for juvenile rearing WUA under the four phases of Alternative 2 show little change in mean rearing WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in juvenile rearing WUA between the four phases of Alternative 2 and the No Action Alternative are mostly small to moderate, ranging from 2.9% higher for wet water years under all four phases of the alternative to 5.5% higher for critically dry water years for all four phases (Attachment N.1, *Stanislaus River Habitat Availability Analysis).* Differences among the four phases are very small (< 0.7%) for all water year types. For the individual months of the juvenile rearing period, the medians of juvenile rearing WUA are much lower in March than in other months (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in the medians between the four phases of Alternative 2 and the No Action Alternative are consistently small.

Overall, the results indicate that fry and juvenile rearing WUA for fall-run Chinook salmon is consistently but modestly higher under the four phases of Alternative 2 than under the No Action Alternative.

Rearing Habitat—ASH Flow Analysis

The results of the Area of Suitable Habitat (ASH) analysis for fall-run fry and juvenile rearing are quite different from the rearing WUA results described above. The mean ASH estimates vary more strongly with water year type for both fry and juvenile fall-run, consistently increasing from critically dry to wet years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the overall relationship between flow and ASH for both life stages determined from modeling and field studies (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in fry and juvenile ASH between the four phases of Alternative 2 and the No Action Alternative are modest, which is consistent with the results of the rearing WUA analyses. For the fry, difference between the four phases of Alternative 2 and the No Action Alternative range from 1.8% lower for dry water years under all four phases of Alternative 2 to 1.6% higher for critically dry years under all phases of Alternative 2 except Alternative 2 With TUCP Without VA. Both increases and reductions are larger for juveniles than

for fry, ranging from 5.4% lower in below normal water years under all phases of Alternative 2 except Alternative 2 With TUCP Without VA to 4.9% higher in dry water years for the same three phases of Alternative 2 (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fall-run fry rearing period, median ASH under the four phases of Alternative 2 relative to the No Action Alternative are higher in February, lower in April, and about the same in March and May.

Overall, the results indicate that fry and juvenile rearing ASH for fall-run Chinook salmon are largely similar under the four phases of Alternative 2 and the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 59 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F upper incipient lethal temperature (UILT) for juveniles during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 60 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis* Table 61 for Orange Blossom Bridge.

Results for the three analyses are summarized in Table O-94. Table O-94, as with all similar temperature analysis results tables in this EIS and as described in Section O.4.14.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability there were two month-water year type combinations (10.0%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-94). For the 75.2°F upper incipient lethal temperature (UILT) for juvenile fall-run Chinook salmon there were no month-water year type combinations (0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration there was zero month-water year type combination (0.0%) with favorable results and 1 combination (5.0%) unfavorable results at Orange Blossom Bridge.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-94).

Overall, the four phases of Alternative 2 would have similar positive water temperature-related effects to fall-run Chinook salmon juvenile rearing and emigration in the Stanislaus River at Orange Blossom Bridge.

Summary

Differences in seasonal operations in the Stanislaus River between the four phases of Alternative 2 and the No Action Alternative during juvenile rearing and emigration periods are expected to a have minor adverse and minor to moderate beneficial impacts on fall-run Chinook salmon. The two rearing habitat analyses suggest a minor to moderate beneficial impacts and minor adverse impacts from flow under the four phases of Alternative 2, depending on water year type. The water temperature model suggests that the four phases of Alternative 2 would have minor beneficial water temperature-related impacts to fall-run Chinook salmon spawning and egg incubation lower American River at Hazel Avenue and Watt Avenue. There would be similar conditions for growth, smoltification, predation vulnerability and pathogen virulence.

Adult Upstream Migration and Holding

Fall-run Chinook salmon adults generally migrate upstream from late September through December with peak migration from late October through early November in the Stanislaus River.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

For the period of adult migration and holding of fall-run Chinook salmon (September through December), CalSim 3 modeling below Goodwin Dam under all phases of Alternative 2 compared to the No Action Alternative indicates that average flow released would generally be very similar (Table O-234 through Table O-237). All water year type projections for Alternative 2 show average flow projections may be the higher in December (7% average increase among all water year types) compared to the No Action Alternative, a minor beneficial effect.

Similar to below Goodwin Dam, for the period of adult migration and holding of fall-run Chinook salmon (September through December), CalSim 3 modeling at the mouth of the Stanislaus under all phases of Alternative 2 compared to the No Action Alternative indicates that average flows released would also generally be similar with the most the variation occurring in below normal and critically dry water years (Table O-238 through Table O-241). In terms of overall averages of all water year types, there is a minor potential beneficial effect during the month of September with an average 5-6% increase in predicted flow across all water year types, with the greatest beneficial effect during a critically dry year with an increase in flows of 42%.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during July through December are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 51 for Orange Blossom Bridge and Table 52 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration during July through December are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 53 for Orange Blossom Bridge and 54 for above the confluence with the San Joaquin River.

Results for the two analyses are summarized in Table O-95. Table O-95, as described in Section O.4.14.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 37.9°F to 68°F successful migration range there were no month-water year type combinations (0.0%) with favorable or unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-95). For the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration there was also no month-water year type combinations (0.0%) with favorable or unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-95).

Overall, the four phases of Alternative 2 would have negligible water temperature related effects on adult fall-run Chinook salmon upstream migration and holding in the Stanislaus River at Orange Blossom Bridge and above the confluence of the San Joaquin River.

Summary

For the period of adult migration and holding of fall-run Chinook salmon (September through December) in the Stanislaus River, CalSim 3 modeling at both Goodwin dam and the mouth during all phases of Alternative 2 compared to the No Action Alternative indicate that average flow released would generally be very similar (Table O-234 through Table O-237). All water year type projections for Alternative 2 show average flow projections may be slightly higher providing a beneficial impact. Water temperature model results indicate there would be negligible impacts on adult fall-run Chinook salmon upstream migration and holding in the Stanislaus River at Orange Blossom Bridge and above the confluence of the San Joaquin River. There would be similar conditions for growth, smoltification, predation vulnerability and pathogen virulence.

O.5.15 White Sturgeon

O.5.15.1 Sacramento River

Spawning and Egg Incubation

Spawning occurs in deep water in the middle and lower Sacramento River from near Verona (~RM 80) to just upstream of Colusa (~RM 156) from late February to early June, peaking during March and April, (Section O.1.3.2.6, *White Sturgeon*). Because the incubation time for white sturgeon is so short, the peak impacts analysis period for incubating eggs is also considered to be March and April.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates of mean monthly flows during the March and April spawning and egg incubation period for white sturgeon at Wilkins Slough under the No Action Alternative and the four phases of Alternative 2 are summarized by phase below.

Mean monthly flow estimates during the spawning and egg incubation period under Alternative 2 With TUCP Without VA range from about 4,200 cfs for April of critically dry water years to about 18,000 cfs for March of wet water years (Table O-190). Alternative 2 Without TUCP Without VA relative to the No Action Alternative is expected to have generally small effects both months (up to 3%), but flows are higher (6%) in April of critically dry water years due to differences in flow (Table O-190). Because white sturgeon spawn in deep pools, these flow levels are likely to be adequate for spawning and egg incubation, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 With TUCP Without VA would have similar flow effects on white sturgeon eggs and embryos relative to the No Action Alternative.

Mean monthly flow estimates during the spawning and egg incubation period under Alternative 2 Without TUCP Without VA range from about 4,900 cfs for April of critically dry water years to about 18,000 cfs for March of wet water years (Table O-191). Alternative 2 Without TUCP Without VA relative to the No Action Alternative is expected to have generally small effects both months (up to 4%), but flows are substantially higher (26%) in April of critically dry water years due to differences in flow (Table O-191). Because white sturgeon spawn in deep pools, these flow levels are likely to be adequate, and possibly beneficial, for spawning and egg incubation, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 Without TUCP Without VA would have similar flow effects on white sturgeon eggs and embryos relative to the No Action Alternative.

Mean monthly flow estimates during the spawning and egg incubation period under Alternative 2 Without TUCP with Delta VA range from about 5,000 cfs for April of critically dry water years to about 18,000 cfs for March of wet water years (Table O-192). Alternative 2 Without TUCP with Delta VA relative to the No Action Alternative is expected to have generally small effects both months (up to 7%), but flows are substantially higher (29%) in April of critically dry water years (Table O-192). Because white sturgeon spawn in deep pools, these flow levels are likely to be adequate, and possibly beneficial, for spawning and egg incubation, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 Without TUCP with Delta VA would have similar flow effects on white sturgeon eggs and embryos relative to the No Action Alternative.

Mean monthly flow estimates during the spawning and egg incubation period under Alternative 2 Without TUCP with Systemwide VA range from about 5,000 cfs for April of critically dry water years to about 18,000 cfs for March of wet water years (Table O-193). Alternative 2 Without TUCP with Systemwide VA relative to the No Action Alternative is expected to have generally small effects in March of all water year types and in April of wet and dry years (up to 4%). However, flows are moderately higher (up to 8%) in April of above normal years and substantially higher (29%) in April of critically dry water years (Table O-193). Because white

sturgeon spawn in deep pools, these flow levels are likely to be adequate, and possibly beneficial, for spawning and egg incubation, so no adverse effects are expected. Therefore, it is concluded that Alternative 2 Without TUCP with Systemwide VA would have similar flow effects on white sturgeon eggs and embryos relative to the No Action Alternative.

Overall, the four phases of Alternative 2 would have similar negligible effects on flow relative to the No Action Alternative for white sturgeon spawning and egg incubation in the Sacramento River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 61°F upper limit for optimal egg incubation during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 291 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 68°F upper limit for embryo hatching during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 292 for Hamilton City.

Results for the two analyses are summarized in Table O-96. Table O-96, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 61°F upper limit for optimal egg incubation, there was one month-water year type combination (5.0% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable results at Hamilton City (Table O-96). For the 68°F upper limit for embryo hatching, there were no combinations (0%) with favorable or unfavorable results at Hamilton City. These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on white sturgeon spawning and egg incubation.
- Results for **Alternative 2 Without TUCP Without VA** are identical to those of Alternative 2 With TUCP Without VA (Table O-96).
- Under **Alternative 2 With TUCP Delta VA** for the 61°F upper limit for optimal egg incubation, there was one month-water year type combination (5.0% of total combinations during the period) with favorable results and one combination (5.0%) with unfavorable results at Hamilton City (Table O-96). For the 68°F upper limit for embryo hatching, there were no combinations (0%) with favorable or unfavorable results at Hamilton City. These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on white sturgeon spawning and egg incubation.
- Results for **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-96).

Overall, the four phases of Alternative 2 would have similar negligible effects on water temperature conditions for white sturgeon spawning and egg incubation in the Sacramento River (Table O-96).

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts to possible beneficial impacts on spawning habitat for all phases, locations, months, and water year types due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on spawning and egg incubation for all phases, locations, months, and water year types due to differences in water temperature.

Larval and Juvenile Rearing and Emigration

The white sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch (Heublein et al. 2017a, Deng et.al 2002). Therefore, since white sturgeon spawn from late February to early June, peaking in March and April, the larval period is considered to be March through June. Juvenile white sturgeon are believed to initiate a secondary dispersal (the primary dispersal occurring at the larval stage) in spring by actively swimming downstream during the night (Heublein et al. 2017a). The juvenile emigration period is considered to be April through July. Therefore, the effects analysis period for larvae and juvenile rearing and emigration is considered to be March through July.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates of mean monthly flows during the white sturgeon larval and juvenile rearing and emigration period from April to July at Wilkins Slough under the No Action Alternative and the four phases of Alternative 2 are summarized by phase below.

Mean monthly flow estimates during the larval and juvenile rearing and emigration period under Alternative 2 With TUCP Without VA range from about 3,400 cfs for May of critically dry water years to about 14,400 cfs for April of wet water years (Table O-190). Alternative 2 With TUCP Without VA relative to the No Action Alternative is expected to have generally small impacts all four months of all water years (up to 5%), with a few exceptions, due to differences in flow. Flows are higher (6%) in April of critically dry water years, and moderately lower (up to 5%) in July of dry years (Table O-190). These flow levels are likely to be adequate for larval and juvenile rearing and emigration, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 With TUCP Without VA would have similar flow effects on white sturgeon larvae and juveniles relative to the No Action Alternative.

Mean monthly flow estimates during the larval and juvenile rearing and emigration period under Alternative 2 Without TUCP Without VA range from about 3,600 cfs for May of critically dry water years to about 14,400 cfs for April of wet water years (Table O-191). Alternative 2 Without TUCP Without VA relative to the No Action Alternative is expected to have generally small effects all four months of all water years (up to 6%), with a few exceptions, due to differences in flow. Flows are moderately higher (10 to 26%) in April, May and July of critically dry water years, and moderately lower (up to 6%) in July of below normal years (Table O-191). These flow levels are likely to be adequate for larval and juvenile rearing and emigration, so no adverse

effects are expected to result. Therefore, it is concluded that Alternative 2 Without TUCP Without VA would have similar flow effects on white sturgeon larvae and juveniles relative to the No Action Alternative.

Mean monthly flow estimates during the larval and juvenile rearing and emigration period under Alternative 2 Without TUCP with Delta VA range from about 3,600 cfs for May of critically dry water years to about 14,400 cfs for April of wet water years (Table O-192). Alternative 2 Without TUCP with Delta VA relative to the No Action Alternative is expected to have generally small effects all four months of all water years (up to 4%), with a few exceptions, due to differences in flow. Flows are moderately higher (10 to 29%) in April, May, and July of critically dry water years, and moderately lower (6%) in July of below normal years (Table O-192). These flow levels are likely to be adequate for larval and juvenile rearing and emigration, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 Without TUCP with Delta VA would have similar flow effects on white sturgeon larvae and juveniles relative to the No Action Alternative.

Mean monthly flow estimates during the larval and juvenile rearing and emigration period under Alternative 2 Without TUCP with Systemwide VA range from about 3,900 cfs for May of critically dry water years to about 14,500 cfs for April of wet water years (Table O-193). Alternative 2 Without TUCP with Systemwide VA relative to the No Action Alternative is expected to have generally small effects all four months of all water years (up to 5%), with a few exceptions, due to differences in flow. Flows are moderately higher (17 to 29%) in April, May, and July of critically dry water years, moderately higher (up to 8%) in April and May of above normal and below normal years, and moderately lower (up to 9%) in June of above normal, below normal, and dry years (Table O-193). These flow levels are likely to be adequate for larval and juvenile rearing and emigration, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 Without TUCP with Systemwide VA would have similar flow effects on white sturgeon larvae and juveniles relative to the No Action Alternative.

Overall, the four phases of Alternative 2 would have negligible effects on flow relative to the No Action Alternative for white sturgeon rearing and emigration in the Sacramento River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66°F limit above which stress is observed in juvenile white sturgeon year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 293 for Hamilton City.

Results for the analysis are summarized in Table O-97. Table O-97, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 66.6°F stress limit for juvenile white sturgeon, there were three month-water year type combinations (5.0% of total combinations during the period, respectively) with favorable results and one combination (1.7%) with unfavorable results at Hamilton City (Table O-97). These results suggest that there would be negligible effects of Alternative 2 With TUCP Without VA on white sturgeon juvenile rearing and emigration.
- Under **Alternative 2 Without TUCP Without VA** for the 66.6°F stress limit for juvenile white sturgeon, there were four month-water year type combinations (6.7% of total combinations during the period, respectively) with favorable results and zero combinations (0%) with unfavorable results at Hamilton City (Table O-97). These results suggest that there would be negligible water temperature-related effects of Alternative 2 Without TUCP Without VA on white sturgeon larval and juvenile rearing and emigration.
- Under **Alternative 2 without TUCP Delta VA** for the 66.6°F stress limit for juvenile white sturgeon, there were three month-water year type combinations (5.0% of total combinations during the period, respectively) with favorable results and one combination (1.7%) with unfavorable results at Hamilton City (Table O-97). These results suggest that there would be negligible water temperature-related effects of Alternative 2 Without TUCP Without VA on white sturgeon larval and juvenile rearing and emigration.
- Results for **Alternative 2 Without TUCP Systemwide VAs** are identical to those for Alternative 2 Without TUCP Delta VA (Table O-97).

Overall, the four phases of Alternative 2 would have similar negligible positive effects on water temperature conditions for white sturgeon larval and juvenile rearing and emigration in the Sacramento River (Table O-97).

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible to beneficial impacts on rearing and emigration for all phases, locations, months, and water year types due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on rearing and emigration for all phases, locations, months, and water year types due to differences in water temperature.

Adult Upstream Migration and Holding

Adults ready for spawning likely move into the lower reaches of the Sacramento River during early winter to begin their upstream migration (Section O.1.3.2.6, *White Sturgeon*). Upstream migration appears to be rapid, with minimal holding time (Schaffter 1997, Heublein et al. 2017a). Based on rapid upstream migration, short egg incubation period, and larval presence in the Sacramento River; the adult upstream migration and holding period is considered to be December to February for this effects analysis.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates of mean monthly flows during the white sturgeon adult upstream migration and holding period from December to February at Wilkins Slough under the No Action Alternative and the four phases of Alternative 2 are summarized by phase below.

Mean monthly flow estimates during the adult upstream migration and holding period under Alternative 2 With TUCP Without VA range from about 6,200 cfs for January of critically dry water years to about 19,900 cfs for February of wet water years (Table O-190). Alternative 2 With TUCP Without VA relative to the No Action Alternative is expected to have generally small effects all three months of all water years (up to 4%) due to flows. These flow levels are likely to be adequate for adult upstream migration, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 With TUCP Without VA would have similar flow effects on white sturgeon adults relative to the No Action Alternative.

Mean monthly flow estimates during the adult upstream migration and holding period under Alternative 2 Without TUCP Without VA range from about 6,300 cfs for January of critically dry water years to about 19,900 cfs for February of wet water years (Table O-191). Alternative 2 Without TUCP Without VA relative to the No Action Alternative is expected to have minimal effects all three months of all water years (up to 4%) due to differences in flows (Table O-191). These flow levels are likely to be adequate for adult upstream migration, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 Without TUCP Without VA would have similar flow effects on white sturgeon adults relative to the No Action Alternative.

Mean monthly flow estimates during the adult upstream migration and holding period under Alternative 2 Without TUCP with Delta VA and Alternative 2 Without TUCP with Systemwide VA range from about 6,200 cfs for January of critically dry water years to about 19,900 cfs for February of wet water years (Table O-192 and Table O-193). Alternative 2 Without TUCP with Delta VA and Alternative 2 Without TUCP with Systemwide VA relative to the No Action Alternative are expected to have minimal effects all three months of all water years (up to 5%) due to flows (Table O-192 and Table O-193). These flow levels are likely to be adequate for adult upstream migration, so no adverse effects are expected to result. Therefore, it is concluded that Alternative 2 Without TUCP with Delta VA and Alternative 2 Without TUCP with Systemwide VA would have similar flow effects on white sturgeon adults relative to the No Action Alternative.

Overall, the four phases of Alternative 2 would have negligible effects on flow relative to the No Action Alternative for white sturgeon upstream migration and holding in the Sacramento River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperature for adult white sturgeon during November through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 294 for Hamilton City.

Results for the analysis are summarized in Table O-98. Table O-98, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 77°F upper limit of suitable water temperature for adult white sturgeon, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results (Table O-98). These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on adult white sturgeon migration and holding in the Sacramento River.
- Results for **Alternative 2 Without TUCP Without VA** Are identical to those of Alternative 2 With TUCP Without VA (Table O-98).
- Results for **Alternative 2 Without TUCP Delta VA** Are identical to those of Alternative 2 With TUCP Without VA (Table O-98).
- Results for **Alternative 2 Without TUCP Systemwide VA** Are identical to those of Alternative 2 With TUCP Without VA (Table O-98).

Overall, the four phases of Alternative 2 would have similar negligible effects on water temperature conditions for adult white sturgeon upstream migration and holding in the Sacramento River (Table O-98).

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on upstream migration and holding for all phases, locations, months, and water year types due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on upstream migration and holding for all phases, locations, months, and water year types due to differences in water temperature.

O.5.15.2 Lower American River

Limited quantitative information is available on the distribution and status of white sturgeon in the lower American River; however, small numbers of adults apparently use the lower American River, as evidenced by sturgeon report cards submitted to the CDFW by anglers in recent years (Section O.1.6.2.1, *Fish Evaluated in the Lower American River*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Adult white sturgeon have been reported by anglers in the lower American River during all months of the year, peaking in March-April and November-December (California Department of Fish and Wildlife 2023i). During all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 2 With TUCP Without VA range from about 724cfs for October of critically dry water years to about 12,283 cfs for February of wet water years (Table O-226). For the full simulation period average, CalSim 3 results indicate that differences in flows during

January through December would generally be minimal (up to 3%) under Alternative 2 With TUCP Without VA compared to the No Action Alternative (Table O-226).

During all months, CalSim 3 estimates of mean monthly flows at H Street under Alternative 2 With TUCP Without VA range from about 604 cfs for October of critically dry water years to about 12,307 cfs for February of wet water years (Table O-230). For the full simulation period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 3%) under Alternative 2 With TUCP Without VA compared to the No Action Alternative (Table O-230).

Adult white sturgeon have been reported by anglers in the lower American River during all months of the year, peaking in March-April and November-December (CDFW 2023g). During all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 2 Without TUCP Without VA range from about 748 cfs for October of critically dry water years to about 12,283 cfs for February of wet water years (Table O-227). For the full simulation period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 3%) under Alternative 2 Without TUCP Without VA compared to the No Action Alternative (Table O-227).

During all months, CalSim 3 estimates of mean monthly flows at H Street under Alternative 2 Without TUCP Without VA range from about 633 cfs for October of critically dry water years to about 12,306 cfs for February of wet water years (Table O-231). For the full simulation period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 4%) under Alternative 2 Without TUCP Without VA compared to the No Action Alternative (Table O-231).

Adult white sturgeon have been reported by anglers in the lower American River during all months of the year, peaking in March-April and November-December (CDFW 2023g). During all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 2 Without TUCP with Delta VA range from about 686 cfs for October of critically dry water years to about 12,287 cfs for February of wet water years (Table O-228). For the full simulation period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 4%) under Alternative 2 Without TUCP with Delta VA compared to the No Action Alternative (Table O-228).

During all months, CalSim 3 estimates of mean monthly flows at H Street under Alternative 2 Without TUCP with Delta VA range from about 574 cfs for October of critically dry water years to about 12,310 cfs for February of wet water years (Table O-232). For the full simulation period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 2 Without TUCP with Delta VA compared to the No Action Alternative (Table O-232).

Adult white sturgeon have been reported by anglers in the lower American River during all months of the year, peaking in March-April and November-December (CDFW 2023g). During all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 2 Without TUCP with Systemwide VA range from about 729 cfs for October of critically dry water years to about 12,293 cfs for February of wet water years (Table O-229). For the full simulation

period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 3%) under Alternative 2 Without TUCP with Systemwide VA compared to the No Action Alternative, with the exception of flows moderately increasing in April (6%) (Table O-229).

During all months, CalSim 3 estimates of mean monthly flows at H Street under Alternative 2 Without TUCP with Systemwide VA range from about 615 cfs for October of critically dry water years to about 12,316 cfs for February of wet water years (Table O-233). For the full simulation period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 4%) except for a moderate increase in April (7%) under Alternative 2 Without TUCP with Systemwide VA compared to the No Action Alternative. Table O-233Overall, white sturgeon are not likely to be affected by changes in flow under all four phases of Alternative 2 compared to the No Action Alternative due to their limited distribution in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperatures for adult white sturgeon year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 77 for Hazel Avenue and Table 78 for Watt Avenue.

Results for the analysis are summarized in Table O-99. Table O-99, as described in Section O.4.15.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 77°F upper limit of suitable water temperatures for adult white sturgeon under each phase of Alternative 2, there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-99). There were also zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue.
- Results for **Alternative 2 Without TUCP Without VA** are identical to those presented with Alternative 2 With TUCP Without VA (Table O-99).
- Results for **Alternative 2 Without TUCP Delta VA** are identical to those presented for Alternative 2 With TUCP Without VA and Alternative 2 Without TUCP Without VA (Table O-99).
- Results for **Alternative 2 Without TUCP Systemwide VAs** are identical to those presented for Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP Delta VA (Table O-99).

These results suggest that the Alternative 2 combinations would have negligible water temperature-related effects on non-spawning white sturgeon in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on non-spawning white sturgeon for all phases, locations, months, and water year types due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on non-spawning white sturgeon for all phases, locations, months, and water year types due to differences in water temperatures.

O.5.15.3 San Joaquin River

Little is known about white sturgeon populations inhabiting the San Joaquin River. White sturgeon spawning in the San Joaquin River was documented for the first time in 2011 and confirmed in 2012. Although most of the sturgeon likely spawn in the Sacramento River, the results of these surveys confirm that white sturgeon do spawn in the San Joaquin River in both wet- and dry-year conditions and may be an important source of production for the white sturgeon population in the Sacramento–San Joaquin River system (Section O.1.8.2.4, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 flows using the Sacramento River as a surrogate, it can be inferred that the spawning period for white sturgeon in the San Joaquin River also occurs in deep water from late February to early June, peaking during March and April, (Section O.1.8.2.4, *White Sturgeon*). Because the incubation time for white sturgeon is so short, the peak effects-analysis period for incubating eggs is also considered to be March and April. Since confirmed spawning events took place in the San Joaquin River, it is reasonable to assume that rearing larvae, emigrating juveniles, and migrating adults are also present in the San Joaquin River, but due to the lack of information on these life stages they are not part of this analysis.

During the evaluated months in the spawning period, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 2 With TUCP Without VA range from about 2,050 cfs for March of critically dry water years to about 12,500 cfs for April of wet water years (Table O-242). CalSim 3 results indicate that differences in flows during March and April would be minimal (up to 2%) under Alternative 2 With TUCP Without VA compared to the No Action Alternative (Table O-242).

During the evaluated months in the spawning period, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 2 Without TUCP Without VA range from about 2,050 cfs for March of critically dry water years to about 12,500 cfs for April of wet water years (Table O-243). CalSim 3 results indicate that differences in flows during March and April would be minimal (up to 2%) under Alternative 2 Without TUCP Without VA compared to the No Action Alternative (Table O-243).

During the evaluated months in the spawning period, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 2 Without TUCP with Delta VA range from about 2,100 cfs for March of critically dry water years to about 12,500 cfs for April of wet water years (Table O-244). CalSim 3 results indicate that differences in flows during March and April would be minimal (up to 5%) under Alternative 2 Without TUCP with Delta VA compared to the No Action Alternative (Table O-244).

During the evaluated months in the spawning period, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 2 Without TUCP with Systemwide VA range from about 2,150 cfs for March of critically dry water years to about 12,500 cfs for April of wet water years (Table O-245). CalSim 3 results indicate that differences in flows during March and April would be minimal (up to 5%) under Alternative 2 Without TUCP with Systemwide VA compared to the No Action Alternative (Table O-245).

Due to spawning occurring in deep pools, it is not anticipated that flows under all phases of Alternative 2 would have an effect on white sturgeon spawning compared to the No Action Alternative.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on white sturgeon in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on spawning white sturgeon due to differences in flow. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.5.15.4 Bay-Delta

Juvenile Rearing and Emigration

White sturgeon are believed to be most abundant within the Bay-Delta region. Juveniles can be found throughout the Delta year-round. Additionally, white sturgeon larvae have been observed to be flushed farther downstream in the Delta and Suisun Bay in high outflow years, but otherwise rear higher in the system (Section O.1.9.1.6, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

<u>CalSim 3 Flows</u>

During all months, CalSim 3 estimates of mean monthly flows in the Sacramento River at Rio Vista under Alternative 2 With TUCP Without VA range from about 3,207 cfs for August of critically dry water years to about 104,680 cfs for February of wet water years (Table O-214). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 2 With TUCP Without VA compared to the No Action Alternative, with a few exceptions. Flows under Alternative 2 With TUCP Without VA in above normal water years would moderately increase in September, while critically dry water years would see increases in November and April and a decrease in August (Table O-214).

CalSim 3 estimates of mean monthly total exports of SWP and CVP under Alternative 2 With TUCP Without VA range from 1,518 cfs for July of critically dry water years to about 10,854 cfs for August of wet water years (Table O-202). For all water year types, CalSim 3 results indicate

that differences in exports during January through December would generally be minimal (up to 5%) under Alternative 2 With TUCP Without VA compared to the No Action Alternative with a few exceptions. Exports would moderately to substantially increase in April and May of all water year types (up to 36%) and moderately increase in March of wet water years (10%), September of above normal water years (10%), and November of critically dry water years (up to 9%). Exports would moderately decrease in June of above normal water years (8%), June and October of below normal water years (up to 9%), January, February, June, and July of dry water years (up to 11%), and January, March, June, July, and August of critically dry water years (up to 13%) (Table O-202). It is not anticipated that changes in exports under Alternative 2 With TUCP Without VA would have an effect on white sturgeon juveniles compared to the No Action Alternative.

During all months, CalSim 3 estimates of mean monthly flows in the Sacramento River at Rio Vista under Alternative 2 Without TUCP Without VA range from about 3,247 cfs for August of critically dry water years to about 104,640 cfs for February of wet water years (Table O-215). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 2 Without TUCP Without VA compared to the No Action Alternative, with a few exceptions. Flows under Alternative 2 Without TUCP Without VA in critically dry water years would see increases in November, March and April, June and July (up to 49%) (Table O-215).

CalSim 3 estimates of mean monthly total exports of SWP and CVP under Alternative 2 Without TUCP Without VA range from 1,419 cfs for August of critically dry water years to about 10,302 cfs for August of wet water years (Table O-203). In most months for all water year types, CalSim 3 results indicate that differences in exports from January through December would be minimal (up to 5%) under Alternative 2 Without TUCP Without VA compared to the No Action Alternative with a few exceptions. Exports would increase in April and May of all water year types (up to 36%) and increase in March of wet water years (9%), September of above normal water years (10%), and July and September of critically dry water years (up to 13%). Exports would decrease in June of above normal water years (8%), June and October of below normal water years (up to 12%), January, February, June, and July of dry water years (up to 11%), and January, February, March, August, and October of critically dry water years (up to 17%) (Table O-203). It is not anticipated that changes in exports under Alternative 2 Without TUCP Without VA would have an effect on white sturgeon juveniles compared to the No Action Alternative.

During all months, CalSim 3 estimates of mean monthly flows in the Sacramento River at Rio Vista under Alternative 2 Without TUCP with Delta VA range from about 3,421 cfs for August of critically dry water years to about 104,538 cfs for February of wet water years (Table O-216). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 2 Without TUCP with Delta VA compared to the No Action Alternative, with a few exceptions. Flows under Alternative 2 Without TUCP with Delta VA in above normal water years would moderately increase in September (7%), while flows in dry water years would moderately decrease in June (6%), and flows in critically dry water years would increase in March through July (up to 48%) (Table O-216).

CalSim 3 estimates of mean monthly total exports of SWP and CVP under Alternative 2 Without TUCP with Delta VA range from 1,752 cfs for August of critically dry water years to about 10,928 cfs for November of wet water years (Table O-204). In most months for all water year types, CalSim 3 results indicate that differences in exports from January through December would be minimal (up to 4%) under Alternative 2 Without TUCP with Delta VA compared to the No Action Alternative with a few exceptions. Exports would moderately increase in May of all water year types (up to 27%), March of wet water years (5%), September of above normal water years (15%), August of below normal and dry water years (up to 18%), and April, May, July, August, September, and December of critically dry water years (up to 55%). Exports would moderately decrease in March, April, and June of above normal water years (up to 20%), March and June of below normal water years (up to 32%), January through April and June of dry water years (up to 21%), and January, March, and November of critically dry water years (up to 16%) (Table O-204). It is not anticipated that changes in exports under Alternative 2 Without TUCP with Delta VA would have an effect on white sturgeon juveniles compared to the No Action Alternative and may benefit juveniles in critically dry water years.

During all months, CalSim 3 estimates of mean monthly flows in the Sacramento River at Rio Vista under Alternative 2 Without TUCP with Systemwide VA range from about 3,500 cfs for August of critically dry water years to about 104,609 cfs for February of wet water years (Table O-217). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 4%) under Alternative 2 Without TUCP with Systemwide VA compared to the No Action Alternative, with a few exceptions. Flows under Alternative 2 Without TUCP with Systemwide VA in above normal water years would increase in April, May, and September (up to 7%). Flows in below normal water years would increase in April (up to 13%). Flows in dry water years would moderately decrease in June (7%) and increase in April, May, and August (up to 10%). Flows in critically dry water years would increase March through July (up to 55%) (Table O-217).

CalSim 3 estimates of mean monthly total exports of SWP and CVP under Alternative 2 Without TUCP with Systemwide VA range from 1,809 cfs for August of critically dry water years to about 10,926 cfs for November of wet water years (Table O-205). In most months for all water year types, CalSim 3 results indicate that differences in exports from January through December would be minimal (up to 5%) under Alternative 2 Without TUCP with Systemwide VA compared to the No Action Alternative with a few exceptions. Exports would moderately increase in May of all water year types (up to 27%), September of above normal water years (14%) and below normal water years (5%), August of below normal and dry water years (up to 19%), and April, May, July, August, and September of critically dry water years (up to 51%). Exports would decrease in March, April, and June of above normal water years (up to 19%), March and June of below normal water years (up to 32%), January, February, March, April, and June of dry water years (up to 21%), and January, February, March and November of critically dry water years (up to 20%) (Table O-205). It is not anticipated that changes in exports under Alternative 2 Without TUCP with Systemwide VA would have an effect on white sturgeon juveniles compared to the No Action Alternative and may benefit juveniles in critically dry water years.

Overall, the four phases of Alternative 2 would have negligible negative effects or minor beneficial effects on flow relative to the No Action Alternative for white sturgeon rearing and emigration in the Bay Delta.

Delta Outflow vs Sturgeon YCI

Differences in year class strength between the four phases of Alternative 2 and the No Action Alternative are expected to be negligible. For additional effects of spring Delta outflow vs white sturgeon YCI under the four phases of Alternative 2, refer to the analysis in Section O.5.11.3.1, *[Green Sturgeon] Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts or possible beneficial impacts on larval and juvenile white sturgeon, depending on phase due to differences in flow.

Potential Changes to Entrainment of White Sturgeon

Alternative 2 relative to the No Action Alternative is expected to have effects on white sturgeon entrainment at the Delta Fish Collection Facilities due to differences in exports. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for white surgeon include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of white sturgeon under Alternative 2 With TUCP Without VA compared to the No Action Alternative at the CVP Jones Pumping Plant were similar for all water year types, whereas at SWP Banks Pumping Plant there was greater loss in wet, above normal, and dry water year types; however, no loss is anticipated in critically dry water year types at either facility (Tables O-100 and O-101). At the SWP Banks Pumping Plant predicted average monthly loss was up to 25% greater for January and May of dry water year types and as low as -2% for March, April, June, November, and December of below normal water year types (Table O-100). Historical loss of white sturgeon at both facilities is rare and infrequent; this is a driver of low values of predicted loss.
- **Alternative 2 Without TUCP Without VA**
    - Predictions from the salvage density model for white sturgeon include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - At the CVP Jones Pumping Plant predicted loss was similar for all water year types, whereas predicted average monthly loss of white sturgeon of Alternative 2 Without TUCP Without VA compared to the No Action Alternative at SWP Banks Pumping Plant was greater in wet and dry water year types; however, no loss is

anticipated in critically dry water year types at either facility (Tables O-100 and O-101). At the SWP Banks Pumping Plant predicted average monthly loss was up to 25% greater for January and May of dry water year types and as low as -1% of below normal water year types (Table O-100).

- **Alternative 2 Without TUCP Delta VA**
    - Predictions from the salvage density model for white sturgeon include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - At the CVP Jones Pumping Plant predicted loss was similar for all water year types, whereas predicted average monthly loss of white sturgeon of Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at SWP Banks Pumping Plant was greater in wet and dry water year types; however, no loss is anticipated in critically dry water year types at either facility (Tables O-100 and O-101). At the SWP Banks Pumping Plant predicted average monthly loss was up to 16% greater for January and May of dry water year types and as low as -4% for March, April, June, November, and December of below normal water year types (Table O-100).
- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for white sturgeon include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - At the CVP Jones Pumping Plant predicted loss was similar for all water year types, whereas predicted average monthly loss of white sturgeon of Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at SWP Banks Pumping Plant was greater in wet and dry water year types and lower in below normal water years; however, no loss is anticipated in critically dry year types at either facility (Tables O-100 and O-101). At the SWP Banks Pumping Plant predicted average monthly loss was up to 12% greater for January and May of dry water year types and as low as -5% for March, April, June, November, and December of below normal water year types (Table O-100).

<u>Summary</u>

Differences in exports between the four phases of Alternative 2 and the No Action Alternative are expected to have negligible impacts on the entrainment of juvenile white sturgeon at both facilities. Modeled results from the quantitative model show possible beneficial and adverse impacts in various phases, months, and water year types, but since white sturgeon are salvaged so rarely, the numbers may not be representative.

Subadult and Adult Residency

White sturgeon are believed to be most abundant within the Bay-Delta region. Non spawning adults can be found throughout the Delta year-round. When not undergoing spawning or ocean migrations, adults and subadults are usually most abundant in brackish portions of the Bay-Delta (Section O.1.9.1.6, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Juveniles, subadults and non-spawning adults are in the Bay Delta year-round, refer to the CalSim 3 flow analysis in the juvenile life stage (Section O.5.15.5.1, *Juvenile Rearing and Emigration*) for changes in flow under all four phases of Alternative 2 compared to the No Action Alternative.

For effects of spring Delta outflow vs white sturgeon YCI under the four phases of Alternative 2, refer to the analysis in Section O.5.11.3.1, *[Green Sturgeon] Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts to possible beneficial impacts on white sturgeon, depending on phase due to differences in flow.

O.5.16 Native Minnows

O.5.16.1 Sacramento River

Sacramento Splittail, Hardhead, and Sacramento Hitch

- **Sacramento Splittail:** Historically, Sacramento splittail was widespread in the Sacramento River from Redding to the Delta (Rutter 1908, as cited in Moyle et al. 2004). This distribution has become somewhat reduced in recent years (Sommer et al. 1997, 2007b). During drier years there is evidence that spawning occurs farther upstream (Feyrer et al. 2005). Adult splittail migrate upstream in the lower Sacramento River to above the mouth of the Feather River and into the Sutter and Yolo Bypasses (Sommer et al. 1997; Feyrer et al. 2005; Sommer et al. 2007b). Each year, mainly during the spring spawning season, a small number of individuals have been documented at the Red Bluff Pumping Plant and the entrance to the GCID intake (Moyle et al. 2004). Most juvenile Sacramento splittail move from upstream areas downstream into the Delta from April through August (Meng and Moyle 1995; Sommer et al. 2007b). The production and recruitment of YOY Sacramento splittail is largely influenced by extent and duration of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Sommer et al. 1997; Moyle et al. 2004; Feyrer et al. 2006).
- **Hardhead:** Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986). They migrate upstream and into tributary streams as far as 45 miles (72.4 km) to spawning sites. Spawning behavior has not been documented, but it is assumed to be similar to that of the

pikeminnow, which deposit their eggs over gravel-bottomed riffles, runs, and at the head of pools (Moyle et al. 1995). Hardhead larvae and juveniles likely inhabit stream margins with abundant cover and move into deeper habitats as they grow larger. Juvenile and adult hardhead are present in the Sacramento River year-round.

- **Sacramento Hitch:** Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta (Moyle et al. 2015). Sacramento hitch were not known to occur in high abundance in the Sacramento watershed, but they are known to prefer shallow backwater areas and historically were observed in the upper and lower Sacramento River and North Delta (Brown & May, 2006; Robinson & Safran, 2014).
- Moyle et al. (2015) summarized habitat and distribution: Spawning takes place mainly in riffles of streams tributary to lakes, river, and sloughs after flows increase in response to spring rains, but spawning requirements are in need of further documentation. Moyle et al. (2015) indicate that YOY hitch spend the next two months after hatching shoaling in shallow water or staying close to aquatic plants before moving out into more open water at around 50-mm fork length.

Potential Changes to Sacramento Splittail, Hardhead, and Sacramento Hitch from Seasonal Operations

CalSim 3 Flows

The greatest factor in determining native minnow spawning success and recruitment is the amount and duration that crucial floodplain spawning areas are inundated during the period of native minnow migration and spawning. In wet years, flows over 22,500 cfs at Tisdale, the first flood control gate, would cause the Tisdale weir to begin spilling into the Sutter Bypass (DWR 2010). Adult migration generally occurs during the late winter with juvenile outmigration into the Delta occurring in spring/early summer. Exact migration, spawning and outmigration timing are not well understood for native minnows, so flows were examined for the months of December through May.

CalSim 3 modeling indicates that average flow released at Keswick Dam under Alternative 2 would generally be similar to flows under No Action Alternative December through May, the range of average flows for the full simulation period are from 6,250 cfs (April with TUCP Without VAs) to 11,918 cfs (February without TUCP systemwide VAs) (Table O-182 through Table O-185). Differences in average flows at Keswick Dam under Alternative 2 are from a 3% reduction (May without TUCP Without VAs) to a 6% increase (April without TUCP systemwide VAs) (Table O-182 through Table O-185). Native minnows need adequate flows to allow access to upstream spawning/rearing habitat, with minimal differences in flows under Alternative 2 the effect on flow to native minnow is likely negligible as compared to the No Action Alternative.

For the full simulation period, and the months of December through May, the difference in average CalSim 3 flow estimates under Alternative 2 compared to the No Action Alternative at Wilkins are minimal, with a range of 1% decrease in flows for May (Alternative 2 With TUCP Without VAs) to a 4% increase in April (Alternative 2 Without TUCP and systemwide VAs) (Table O-190 through Table O-193). Under Alternative 2 CalSim 3 flow estimates at Wilkins

would have a negligible effect on native minnow spawning and migration as compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 75°F observed range of suitable water temperatures for Sacramento splittail during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 307 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 84.2°F range of preferred temperatures in lab and field observations for Sacramento hitch non-spawning adults year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 308 for Keswick Dam, 309 for Red Bluff Diversion Dam, and 310 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 64°F optimal water temperature range for hardhead spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 311 for Keswick Dam and 312 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature outside the 57.2°F to 78.8°F commonly observed range of temperatures for non-spawning adult hardhead year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 314 for Keswick Dam and 315 for Red Bluff Diversion Dam.

Results for the four analyses are summarized in Table O-102. Table O-102, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 45°F to 75°F observed range for suitable Sacramento splittail spawning, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Hamilton City (Table O-102). For the 77-84.2°F preferred range for non-spawning Sacramento hitch, there were no combinations (0%) with favorable or unfavorable results at any location analyzed. For the 59-64°F optimal hardhead spawning range, there were zero and one combination (0% and 6.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were zero and six combinations (0% and 40.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59-64°F commonly observed range for non-spawning adult hardhead. For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there were one and zero combinations (1.7% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were zero and three combinations (0% and 5.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 2 With TUCP Without VA on native minnows in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 45°F to 75°F observed range for suitable Sacramento splittail spawning, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Hamilton City (Table O-102). For the 77°F to 84.2°F preferred range for non-

spawning Sacramento hitch, there were no combinations (0%) with favorable or unfavorable results at any location analyzed. For the 59°F to 64°F optimal hardhead spawning range, there were zero and one combinations (0% and 6.7%, respectively) with favorable results at Keswick Dam and RBDD. There were zero and five combinations (0% and 33.3%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there were no combinations (0%) with favorable results at either Keswick Dam and RBDD, there were two and three combinations (0% and 6.7%, respectively) with unfavorable results at either Keswick Dam and RBDD, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 2 Without TUCP Without VA on native minnows in the Sacramento River.

- Under **Alternative 2 Without TUCP Delta VA** for the 45°F to 75°F observed range for suitable Sacramento splittail spawning, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Hamilton City (Table O-102). For the 77°F to 84.2°F preferred range for non-spawning Sacramento hitch, there were no combinations (0%) with favorable or unfavorable results at any location analyzed. For the 59°F to 64°F optimal hardhead spawning range, there were no combinations (0%) with favorable results at both locations analyzed. There were zero and five combinations (0% and 33.3%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there were one and zero combinations (1.7% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were zero and four combinations (0% and 6.7%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 2 Without TUCP Delta VA on native minnows in the Sacramento River.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 45°F to 75°F observed range for suitable Sacramento splittail spawning, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Hamilton City (Table O-102). For the 77°F to 84.2°F preferred range for non-spawning Sacramento hitch, there were no combinations (0%) with favorable or unfavorable results at any location analyzed. For the 59°F to 64°F optimal hardhead spawning range, there were no combinations (0%) with favorable results at both locations analyzed. There were zero and four combinations (0% and 26.7%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there was one and zero combinations (1.7% and 0%, respectively) with favorable results at both Keswick Dam and RBDD, respectively. There were zero and five combinations (0% and 8.3%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 2 Without TUCP Systemwide VAs on native minnows in the Sacramento River.

Overall, the four phases of Alternative 2 would have similar negative effects on water temperature conditions for native minnows in the Sacramento River (Table O-102).

Summary

Seasonal operations impact on native minnows would be likely be negligible or slightly adverse based on the CalSim 3 and temperature analysis with a few exceptions. Differences in flow under Alternative 2 are minimal so impacts to native minnow would only be temperature related. Under the four phases of Alternative 2 compared to the No Action Alternative, water temperatures in the Sacramento River at RBDD would likely have an adverse impact on spawning and non-spawning hardhead. Water temperature related impacts on Sacramento splittail and hitch are likely negligible below Keswick Dam and at RBDD.

O.5.16.2 Clear Creek

Hardhead

According to Moyle et al. 2015, hardhead mainly occupy canyon reaches and deep pools in Clear Creek. Hardhead are one of the non-target species regularly caught in the RSTs in lower Clear Creek (Schraml and Chamberlain 2019a, 2019b, 2020, and 2021). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986). They migrate upstream and into tributary streams as far as 45 miles (72.4 km) to spawning sites.

Potential Changes to Hardhead from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning flows in Clear Creek the CalSim 3 modeling results show that throughout the full simulation period average flows in Clear Creek are higher under Alternative 2 with the exception of a 10% reduction in February. Under Alternative 2 average flows in Clear Creek ranged from 220 cfs (April) to 301 cfs (January and February)(Table O-218 through Table O-221). Even with a 10% reduction in February, flows would remain generally high during the period of hardhead spawning and migration so the effect of seasonal operations under Alternative 2 compared to the No Action Alternative would likely be negligible.

Hardhead are present in Clear Creek all months of the year. During the full simulation period and for all months utilizing the CalSim 3 modeling results, average flows under Alternative 2 had a range from 112 cfs (July, without TUCP systemwide VAs) to 301 cfs (January and February, with TUCP Without VAs) (Table O-218 through Table O-221). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from 31% lower (June, with TUCP Without VAs) to 36% higher (May, without TUCP with Delta VAs) (Table O-218 through Table O-221). With the decrease in flows in February flows would still remain relatively high in the winter, but during the fall a substantial reduction in flows would likely have a negative effect on hardhead occupying Clear Creek by limiting available habitat, and prey availability.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 64°F optimal water temperature range for hardhead spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of

months with water temperature outside the 57.2°F to 78.8°F commonly observed range of temperatures for hardhead spawning year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 307 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-103. Table O-103, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 59-64°F optimal hardhead spawning range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results (Table O-103). For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there was one combination (1.7%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on native minnows in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-103).

Overall, the four phases of Alternative 2 would have similar negligible effects on water temperature conditions for native minnows in Clear Creek (Table O-103).

Summary

There are likely negligible impacts of seasonal operations on Hardhead in Clear Creek based on temperature and simulated flow analysis for the four phases of Alternative 2 as compared to the No Action Alternative. Both the flow and temperature analysis show that Alternative 2 would have little to no difference in habitat suitability for all stages of hardhead as compared to the No Action Alternative.

O.5.16.3 Lower American River

Hardhead and Sacramento Splittail

- **Hardhead:** The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are fairly common in the lower reaches of the lower American River. Hardhead are fairly common year-round in the lower reaches of the lower American River (Moyle 2002). Although migratory behavior of hardhead in the lower American River individuals is unknown, individuals from other large rivers, such as the Sacramento River, migrate into tributary streams during April and May. Hardhead typically spawn between April and May (Moyle 2002). Although hardhead early life history is largely unknown, young individuals likely remain along stream edges with dense cover and move into deeper water as they grow, which allows migrants to move back downstream in the current (Moyle 2002).

- **Sacramento Splittail:** Splittail likely spawn in the lower reaches of the lower American River (Sommer et al. 2008; Moyle et al. 2004). Because upstream migration is more directed and fish tend to swim farther upstream during wet years (Moyle 2002), more individuals are expected to use the lower American River in wet years. Although juvenile splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks of rearing on floodplain habitat (Bureau of Reclamation 2008). Most juveniles move downstream into the Delta from April to August (Meng and Moyle 1995). The primary factor potentially limiting the lower American River population of Sacramento splittail is availability of inundated floodplains for spawning and rearing habitats (Moyle et al. 2004).

Potential Changes to Hardhead and Sacramento Splittail from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning for flows in the lower American River below Nimbus the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 2 average flows in the lower American River below Nimbus ranged from 3,587 cfs (May, without TUCP with Delta VAs) to 6,349 cfs (February, with TUCP Without VAs) (Table O-226 through Table O-229). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 2% reduction (January, without TUCP with Delta VAs) to a 6% increase (April, without TUCP Systemwide VAs) (Table O-226 through Table O-229). With minimal differences in flows native minnow migration and spawning would likely have a negligible affect under Alternative 2 compared to the No Action Alternative, with the exception of critically dry water year types where a reduction in flows during the beginning of the migration period may limit migration of native minnows into the lower American River.

For all months of the year, and for the full simulation period, CalSim 3 estimates of mean monthly flows below Nimbus Dam under the four phases of Alternative 2 are from 1,433 cfs (October, without TUCP and Delta VAs) to 6,349 cfs (February, with TUCP Without VAs) (Table O-226 through Table O-229). The difference in average flows under Alternative 2 as compared to the No Action Alternative for the full simulation period range from a 4% reduction (October, without TUCP with Delta VAs) to a 6% increase (April without TUCP systemwide VAs) (Table O-226 through Table O-229). With minimal differences in flows native minnow occupying the lower American River would likely have a negligible affect under Alternative 2 compared to the No Action Alternative. The only exception would be in critically dry water year types where a reduction in flows during the beginning of the migration period may limit migration of native minnows but would likely have little effect on juveniles and non-spawning adults in the lower American River.

During the December through May period for adult migration and spawning for flows in the lower American River at H street, the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 2 average flows in the lower American River at H street ranged from 3,462 cfs (April, with TUCP Without VAs) to 6,339 cfs (February, with TUCP Without VAs) (Table O-230 through Table O-233). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 2% reduction (December, without TUCP and Delta VAs) to a 6% increase (April, without TUCP Systemwide VAs) for the full simulation period (Table O-230 through Table O-233). With minimal differences in flows native minnow migration and spawning would likely have a negligible affect under Alternative 2 compared to the No Action Alternative, with the exception of critically dry water year types where adult migration and spawning may be limited during the beginning of the migration period.

During all months, and the full simulation period, CalSim 3 estimates of mean monthly flows at H Street under Alternative 2 range from 1,334 (October, without TUCP with Delta VAs) to 6,339 cfs (February, with TUCP Without VAs) (Table O-230 through Table O-233). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 6% reduction (August, without TUCP and systemwide VAs) to a 6% increase (April, without TUCP systemwide VAs) for the full simulation period (Table O-230 through Table O-233). With minimal differences in flows native minnow occupying the lower American River would likely have a negligible affect under Alternative 2 compared to the No Action Alternative. The only exception would be in critically dry water year types where a reduction in flows during the beginning of the migration period may limit migration of native minnows but would likely have little effect on juveniles and non-spawning adults in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 75°F water temperature range observed for Sacramento splittail suitable spawning during February through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 87 for Hazel Avenue and Table 88 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the outside the 59°F to 64°F water temperature optimal range for hardhead spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 89 for Hazel Avenue and Table 90 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the outside the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 91 for Hazel Avenue and Table 92 for Watt Avenue.

Results for these three analyses are summarized in Table O-104. Table O-104, as described in Section O.4.16.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 45°F to 75°F water temperature range observed for suitable spawning for Sacramento splittail under each phase of Alternative 2, there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-104). There were also zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59°F to 64°F water temperature optimal range for hardhead spawning there were one and one month-water year type combinations (6.7% and 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and two month-water year type combinations (13.3% and 13.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were zero and one month-water year type combinations (0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and two month-water year type combinations (3.3% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Without VA** for the 45°F to 75°F water temperature range observed for suitable spawning for Sacramento splittail under each phase of Alternative 2, there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-104). There were also zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59°F to 64°F water temperature optimal range for hardhead spawning there were zero and one month-water year type combinations (0% and 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and zero month-water year type combinations (6.7% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and two month-water year type combinations (1.7% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Delta VA** for the 45°F to 75°F water temperature range observed for suitable spawning for Sacramento splittail under each phase of Alternative 2, there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-104). There were also zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59°F to 64°F water temperature optimal range for hardhead spawning there were zero and two month-water year type combinations (0% and 13.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two month-water year type combinations (13.3%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were zero and one month-water year type combinations (0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and three month-water year type combinations (3.3% and 5.0% respectively) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 45°F to 75°F water temperature range observed for suitable spawning for Sacramento splittail under each phase of Alternative 2, there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-104). There were also zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59°F to 64°F water temperature optimal range for hardhead spawning there was one month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue. There were two and three month-water year type combinations (13.3% and 20.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were two and three month-water year type combinations (3.3% and 5.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, these results suggest all phases of Alternative 2 would small positive and negative water temperature-related effects to native minnow spawning and non-spawning adults in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There are likely beneficial and adverse impacts of seasonal operations on native minnow in the lower American River based on the difference in simulated flows for all phases of Alternative 2 compared to the No Action Alternative. The water temperature analysis for the lower American River at Hazel and Watt Avenue indicates that there would be both beneficial and adverse water temperature-related effects to native minnows in the lower American River. Under the four phases of Alternative 2 differences in flows are minimal, so adult migration and spawning would likely be unaffected, but the proportion of native minnows remaining in the lower American river would be negatively impacted by sub-optimal temperatures as compared to the No Action Alternative.

O.5.16.4 Stanislaus River

Hardhead

The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are a frequent catch in the lower Stanislaus River (Bradbury and Hickey 2019). The Stanislaus River compared to other systems in the San Joaquin River watershed has higher discharge and albeit slightly cooler water for most of the year. Due to the more stream-like conditions the Stanislaus River is occupied by many native fish, including hardhead. The increased discharge has also limited many non-native fishes, concentrating them in the lower reaches. Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).

Potential Changes to Hardhead from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning for flows in the Stanislaus River at the confluence with the San Joaquin the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are similar under Alternative 2. Under Alternative 2 average flows in the Stanislaus River at the confluence ranged from 531 cfs (December) to 1,160 cfs (May, with TUCP Without VAs) (Table O-238 through Table O-241). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 3% reduction (May) to a 4% increase (December, without TUCP with Delta VAs) (Table O-238 through Table O-241). With little difference in flows hardhead migration and spawning would likely be negligibly impacted under Alternative 2 compared to the No Action Alternative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the Stanislaus River at the confluence of the San Joaquin under Alternative 2 range from 345 cfs (July, with TUCP Without VAs) to 1,160 cfs (May, with TUCP Without VAs) (Table O-238 through Table O-241).The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 3% reduction (May) to a 10% increase (August, without TUCP Without VAs) (Table O-238 through Table O-241). Hardhead are present in the Stanislaus River all months of the year. With similar flows most of the year and a slight increase during the fall, hardhead occupying the Stanislaus River would likely have a negligible or positive effect under Alternative 2 as compared to the No Action Alternative.

During the December through May period for adult migration and spawning for flows in the Stanislaus River below Goodwin Dam the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 2 average flows in the Stanislaus River below Goodwin Dam ranged from 527 cfs (December, with TUCP Without VAs) to 1,048 cfs (February, with TUCP Without VAs) (Table O-234 through Table O-237). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 8% reduction (April) to a 7% increase (February) (Table O-234 through Table O-237). With minimal differences in flows hardhead migration and spawning would likely be negligibly impacted under Alternative 2 compared to the No Action Alternative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the Stanislaus River below Goodwin Dam under Alternative 2 had a range from 306 cfs (November, without TUCP Without VAs) to 1,048 cfs (February, with TUCP Without VAs) (Table O-234 through Table O-237). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 8% reduction (April) to a 13% increase (August, without TUCP systemwide VAs) for the full simulation period, and all months (Table O-234 through Table O-237). Hardhead are present in the Stanislaus River for all months of the year. With little difference in flows and slightly higher flows in the fall, hardhead would likely have a negligible or positive effect under Alternative 2 as compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the outside the 59°F to 64°F water temperature optimal range for hardhead spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 868 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the outside the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 69 for Orange Blossom Bridge.

Results for these two analyses are summarized in Table O-105. Table O-105, as described in Section O.4.16.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 59°F to 64°F water temperature optimal range for hardhead spawning, there was one month-water year type combination (6.7%) with favorable results and zero month-water year type combinations (0%) with unfavorable results at Orange Blossom Bridge (O-105). For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were two month-water year type combinations (3.3%) with favorable results and four month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-105).

Overall, the four phases of Alternative 2 would have negligible water temperature-related effects on native minnows in the Stanislaus River at Orange Blossom Bridge.

Summary

The difference in simulated flows under the four phases of Alternative 2 as compared to the No Action Alternative are minimal, so flow-related impacts to hardhead would likely be negligible. However, based off the temperature analysis for the Stanislaus River at Orange Blossom Bridge, the frequency of sub-optimal temperatures for both spawning adults and non-spawning adults/juveniles would be higher under the four phases of Alternative 2 compared to the No Action Alternative. Under the four phases of Alternative 2 differences in flows are minimal, so adult migration and spawning would likely be unaffected, but the proportion of hardhead remaining in the Stanislaus River would be negatively affected by sub-optimal temperatures as compared to the No Action Alternative.

O.5.16.5 San Joaquin River

Sacramento Splittail, Hardhead, and Sacramento Hitch

- **Sacramento Splittail:** Historically, Sacramento splittail were widespread in the San Joaquin River and found upstream to Tulare and Buena Vista lakes, where they were harvested by native peoples (Moyle et al. 2004). Today, Sacramento splittail likely ascend the San Joaquin River to Salt Slough during wet years (Baxter 1999). During dry years, Sacramento splittail are uncommon in the San Joaquin River downstream of the Tuolumne River (Moyle et al. 2004).

  The population of Sacramento splittail is largely influenced by extent and period of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Moyle et al. 2004).

- **Hardhead:** In the San Joaquin drainage, hardhead are present throughout tributary streams but are largely absent from the valley reaches of the San Joaquin River (Moyle et al. 2015, Moyle and Nichols 1973, Saiki 1984). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).

- **Sacramento Hitch:** Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta, but are now absent from the San Joaquin River and tributaries between Friant Dam and the Merced River (Moyle et al. 2015). Sacramento hitch are occasionally captured in low numbers in the lower San Joaquin River in the Mossdale trawl monitoring program (Interagency Ecological Program et al. 2022).

Potential Changes to Sacramento Splittail, Sacramento Hitch, and Hardhead from Seasonal Operations

During the December through May period for adult migration and spawning for flows in the San Joaquin at Vernalis the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 2 average flows in the San Joaquin at Vernalis ranged from 2,884 cfs (December) to 6,391 cfs (February, without TUCP with Delta VAs) (Table O-242 through Table O-245). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 1% reduction (May) to a 1% increase (December) for the full simulation period, and months of December through May (Table O-242 through Table O-245). With minimal differences in flows native minnow migration and spawning would likely have a negligible affect under Alternative 2 compared to the No Action Alternative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the San Joaquin at Vernalis under Alternative 2 range from 1,425 cfs (August, with TUCP Without VAs) to 6,449 cfs (February, without TUCP and Delta VAs) (Table O-242 through Table O-245). The difference in average flows under Alternative 2 compared to the No Action Alternative had a range from a 1% reduction (May) to a 3% increase (August, without TUCP Without VAs) (Table O-242 through Table O-245). Presence of native minnows in the San Joaquin are not well known, but it is likely that many species are present year-round. With

minimal differences in flow under Alternative 2 compared to the No Action Alternative the effect of flow on native minnows is likely negligible.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on native minnows in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

Summary

Based off the CalSim 3 flow analysis differences in flow under the four phases of Alternative 2 would be minimal. Many native minnows likely use the San Joaquin and its tributaries for spawning and rearing, adequate flow is also necessary for spawning adults to access spawning areas. Without a substantial difference in flow, impacts to native minnow under the four phases of Alternative 2 compared to the No Action Alternative would be likely be negligible. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

O.5.16.6 Bay-Delta

Hardhead, Sacramento Hitch, and Sacramento Splittail

- **Hardhead:** The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are present in low abundance in the San Francisco Estuary and Delta. Brown and Michniuk (2007) electrofished parts of the Bay-Delta in the 1980's and 2000's and captured small numbers of hardhead. Retrieval of hardhead at the SWP/CVP south Delta fish salvage facilities remain relatively low (California Department of Water Resources 2020).

- **Sacramento Hitch:** The species is distributed in the Sacramento River Basin, in low numbers in the San Joaquin River Basin, and occasionally captured during monitoring programs in the Delta (Moyle et al. 2015; Interagency Ecological Program et al. 2022). Monitoring data suggests year round presence in the Delta (Interagency Ecological Program et al. 2022).

- **Sacramento Splittail:** Adult Sacramento splittail typically migrate upstream from brackish areas in January and February and spawn in freshwater, particularly on inundated floodplains when they are available, in March and April (Sommer et al. 1997; Moyle et al. 2004; Sommer et al. 2008). A substantial amount of splittail spawning occurs in the Yolo and Sutter Bypasses and the Cosumnes River area of the Delta (Moyle et al. 2004).

  Although juvenile Sacramento splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks or months of rearing in floodplain habitats along the rivers (Feyrer et al. 2006). Juveniles move downstream into the Delta from April to August (Meng and Moyle 1995; Feyrer et al. 2005). Sacramento splittail recruitment is largely limited by extent and period of inundation of floodplain spawning habitats, with abundance observed to spike following wet years and dip after dry years (Moyle et al. 2004).

Potential Changes to Sacramento Splittail, Sacramento Hitch, and Hardhead from Seasonal Operations

CalSim 3 Flows

For many species of native minnow, it has been shown that changes in export flows can lead to higher levels of entrainment which can potentially influence population dynamics. Certain species such as Sacramento splittail are known to utilize the Delta for many portions of their life history so flows into the Delta will have a strong effect on these fish by limiting habitat, prey availability and access to spawning areas. Since many native minnows occupy the Delta year-round, flows and exports were examined for all months of the year.

During all months and for the full simulation period, CalSim 3 estimates of Delta outflow would be similar under Alternative 2 for most months compared to the No Action Alternative. CalSim 3 estimates of average Delta outflow have a range from about 4,500 cfs (August, without TUCP and Delta VAs) to over 58,000 cfs (February, without TUCP Without VAs) for Alternative 2 and for the full simulation period (Table O-206 through Table O-209). Differences in average outflow under Alternative 2 as compared to the No Action Alternative would be from a 6% reduction (May, with TUCP Without VAs) to a 6% increase (April, without TUCP systemwide VAs) (Table O-206 through Table O-209). With minimal differences in Delta outflow under Alternative 2 the effect on native minnows would likely be negligible as compared to the No Action Alternative.

CalSim 3 estimates of mean monthly average flow for the total exports of SWP and CVP under Alternative 2 range from 4,213 cfs (April, without TUCP and Delta VAs) to 8,313 cfs (July, without TUCP systemwide VAs) (Table O-202 through Table O-205). For the full simulation period, CalSim 3 results indicate that differences in average exports for Alternative 2 would be minimal for most of the year having a slight reduction in March followed by an increase in exports in April/May, with May having a substantial increase for all components of Alternative 2. The range of average export flow difference under Alternative 2 compared to the No Action Alternative for the full simulation period were from a 12% reduction in exports (March, without TUCP with Delta VAs) to a 25% increase in exports (May, with TUCP Without VAs) (Table O-202 through Table O-205). Although differences in export flows under Alternative 2 compared to the No Action Alternative are minimal for most of the year, increased exports during April/May would likely cause an increase in entrainment for many native minnows and for all life stages. Given that higher levels of entrainment would be expected at a crucial time of the year, Alternative 2 would likely have a negative effect on native minnows as compared to the No Action Alternative.

Summary

With minimal differences in Delta outflow under Alternative 2 the impact on native minnows would likely be negligible as compared to the No Action Alternative. Although differences in export flows under Alternative 2 compared to the No Action Alternative are minimal for most of the year, increased exports during April/May would likely cause an increase in entrainment for many native minnows. Given that higher levels of entrainment would be expected at a crucial time of the year, Alternative 2 would likely have a negative impact on native minnows with as compared to the No Action Alternative.

Potential Changes to Entrainment of Sacramento Splittail, Sacramento Hitch, and Hardhead

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on native minnows at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Sacramento Splittail: Alternative 2 With TUCP Without VAs**
    - Predictions from the salvage density model for Sacramento splittail include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of Sacramento splittail at SWP Banks Pumping Plant for all months of the year and all water year types Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative, up to 62% greater for the above normal water year types (Table O-106). Predicted average monthly loss of Sacramento splittail at CVP Jones Pumping Plant for all months of the year and all water year types Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for wet, above normal, and below normal water year types, for dry and critically dry water year types predicted loss was lower under Alternative 2 With TUCP. For all water year types Alternative 2 With TUCP Without VAs as compared to the No Action Alternative at Jones had a range from up to 2% greater for above normal water year types to 14% lower for dry water year types, it should also be noted that in critically dry water year types predicted loss only occurred for 6 months of the year (Table O-107). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.
- **Sacramento Splittail: Alternative 2 Without TUCP Without VAs**
    - Predictions from the salvage density model for Sacramento splittail include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of Sacramento splittail at SWP Banks Pumping Plant for all months of the year and all water year types, Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for all but critically dry water year types, with up to 62% greater for the above normal water year types and 5% lower for critically dry water year types (Table O-106). Predicted average monthly loss of Sacramento splittail at CVP Jones Pumping Plant for all months of the year and all water year types Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for wet, above normal, and critically dry water year types, for below normal, and dry water year types

predicted loss was lower under Alternative 2 Without TUCP Without VAs. For all water year types Alternative 2 With TUCP as compared to the No Action Alternative at Jones had a range from up to 2% greater for above normal water year types to 13% lower for dry water year types, it should also be noted that in critically dry water year types predicted loss only occurred for 6 months of the year (Table O-107). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.

- **Sacramento Splittail: Alternative 2 Without TUCP Delta VAs**
    - Predictions from the salvage density model for Sacramento splittail include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of Sacramento splittail at SWP Banks Pumping Plant for all months of the year and all water year types Alternative 2 Without TUCP Delta VAs was greater than predicted average monthly loss under the No Action Alternative for all but critically dry water year types, with up to 47% greater for wet and above normal water year types and 4% lower for critically dry water year types (Table O-106). Predicted average monthly loss of Sacramento splittail at CVP Jones Pumping Plant for all months of the year and all water year types Alternative 2 Without TUCP Delta VAs was equal or lower than predicted average monthly loss under the No Action Alternative for all water year types except for critically dry water year types. For all water year types Alternative 2 Without TUCP Delta VAs as compared to the No Action Alternative at Jones had a range from up to 13% lower for dry water year types to 4% higher for critically dry water year types, it should also be noted that in critically dry water year types predicted loss only occurred for six months of the year (Table O-107). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.
- **Sacramento Splittail: Alternative 2 Without TUCP Systemwide VAs**
    - Predictions from the salvage density model for Sacramento splittail include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of Sacramento splittail at SWP Banks Pumping Plant for all months of the year and all water year types Alternative 2 Without TUCP Systemwide VAs was greater than predicted average monthly loss under the No Action Alternative for all but critically dry water year types, with up to 48% greater for wet water year types and 4% lower for critically dry water year types (Table O-106). Predicted average monthly loss of Sacramento splittail at CVP Jones Pumping Plant for all months of the year and all water year types Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly loss under the No Action Alternative for above normal, below normal and dry water year types, predicted loss was higher for wet, and critically dry

water year types. For all water year types Alternative 2 Without TUCP Systemwide VAs as compared to the No Action Alternative at Jones had a range from up to 12% lower for dry water year types to 3% higher for critically dry water year types, it should also be noted that in critically dry water year types predicted loss only occurred for 6 months of the year (Table O-107). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.

- **Sacramento Hitch: Alternative 2 With TUCP Without VAs**
    - Predictions from the salvage density model for Sacramento hitch include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of Sacramento hitch at SWP Banks Pumping Plant for all months of the year and all water year types Alternative 2 With TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for all water year types except dry water year types. Predicted average monthly loss at Banks under Alternative 2 With TUCP Without VAs had a range from 5% lower for dry water year types to 178% higher for above normal water year types, there was no predicted loss for critically dry water year types. (Table O-110). Predicted average monthly loss of Sacramento hitch at CVP Jones Pumping Plant for the months of March through April and all water year types Alternative 2 With TUCP Without VAs was greater or equal than predicted average monthly loss under the No Action Alternative. For all water year types Alternative 2 With TUCP Without VAs as compared to the No Action Alternative at Jones had a predicted loss that was equal for all but wet water year types, which had a 10% increase in predicted loss, no fish were predicted to be lost in dry and critically dry water year types. It should be noted that loss of Sacramento hitch at both facilities is rare and infrequent, with such low values of predicted loss, the percent differences may not be representative (Table O-111). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.
- **Sacramento Hitch: Alternative 2 Without TUCP Without VAs**
    - Predictions from the salvage density model for Sacramento hitch include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of Sacramento hitch at SWP Banks Pumping Plant for all months of the year and all water year types Alternative 2 Without TUCP Without VAs was greater than predicted average monthly loss under the No Action Alternative for wet, and above normal water year types, predicted loss was lower for below normal, and dry water year types, there was no predicted loss for critically dry water year types. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Without VAs had a range from 5% lower for dry

water year types to 177% higher for above normal water year types (Table O-110). Predicted average monthly loss of Sacramento hitch at CVP Jones Pumping Plant for the months of March through April and all water year types Alternative 2 Without TUCP Without VAs was greater or equal than predicted average monthly loss under the No Action Alternative. The range of predicted loss for Sacramento hitch at Jones under Alternative 2 Without TUCP Without VAs compared to the No Action Alternative was from 0% in above normal water year types to 11% higher for wet water year types, no fish were predicted to be lost in dry and critically dry water year types. It should be noted that loss of Sacramento hitch at both facilities is rare and infrequent, with such low values of predicted loss, the percent differences may not be representative. (Table O-111). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.

- **Sacramento Hitch: Alternative 2 Without TUCP Delta VAs**
    - Predictions from the salvage density model for Sacramento hitch include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of Sacramento hitch at SWP Banks Pumping Plant for all months of the year and all water year types Alternative 2 Without TUCP Delta VAs was greater than predicted average monthly loss under the No Action Alternative for all water year types, except for dry water year types, there was no predicted loss for critically dry water year types. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Delta VAs had a range from 1% lower for dry water year types to 49% higher for above normal water year types (Table O-110). Predicted average monthly loss of Sacramento hitch at CVP Jones Pumping Plant for the months of March through April and all water year types Alternative 2 Without TUCP Delta VAs was lower than predicted average monthly loss under the No Action Alternative. The range of predicted loss for Sacramento hitch at Jones under Alternative 2 Without TUCP Delta VAs compared to the No Action Alternative was from 10% lower in wet water year types to 33% lower for above and below normal water year types, no fish were predicted to be lost in dry and critically dry water year types. It should be noted that loss of Sacramento hitch at both facilities is rare and infrequent, with such low values of predicted loss, the percent differences may not be representative. (Table O-111). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.
- **Sacramento Hitch: Alternative 2 Without TUCP Systemwide VAs**
    - Predictions from the salvage density model for Sacramento hitch include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.

- Predicted average monthly loss of Sacramento hitch at SWP Banks Pumping Plant for all months of the year and all water year types. Alternative 2 Without TUCP Systemwide VAs was greater than predicted average monthly loss under the No Action Alternative for all water year types, there was no predicted loss for critically dry water year types. Predicted average monthly loss at Banks under Alternative 2 Without TUCP Systemwide VAs had a range from 3% higher for dry water year types to 49% higher for above normal water year types (Table O-110). Predicted average monthly loss of Sacramento hitch at CVP Jones Pumping Plant for the months of March through April and all water year types Alternative 2 Without TUCP Systemwide VAs was lower than predicted average monthly loss under the No Action Alternative. The range of predicted loss for Sacramento hitch at Jones under Alternative 2 Without TUCP Systemwide VAs compared to the No Action Alternative was from 11% lower in wet water year types to 36% lower for below normal water year types, no fish were predicted to be lost in dry and critically dry water year types. It should be noted that loss of Sacramento hitch at both facilities is rare and infrequent, with such low values of predicted loss, the percent differences may not be representative. (Table O-111). For detailed information on average monthly loss by water year type, see Attachment I.2, Salvage Density Model Loss Simulation.

- **Hardhead: Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for hardhead include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Whereas at the CVP Jones Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of hardhead of Alternative 2 With TUCP Without VA compared to the No Action At the SWP Banks Pumping Plant was greater all water year types, except in below normal and dry water year types when no fish are expected (Tables O-108 and O-109). At the SWP Banks Pumping Plant predicted average monthly loss was between 19% and 178% greater in September of critically dry water years and April of above normal water years, respectively (Table O-108).
- **Hardhead: Alternative 2 Without TUCP Without VA**
    - Predictions from the salvage density model for hardhead include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Whereas at the CVP Jones Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of hardhead of Alternative 2 Without TUCP Without VA compared to the No Action Alternative at SWP Banks Pumping Plant was greater all water year types, except in below normal and dry water year types when no fish are expected (Tables O-108 and O-109). At the SWP Banks Pumping Plant predicted average monthly loss was

between 16% and 177% greater in April of wet and above normal water year, respectively (Table O-108).

- **Hardhead: Alternative 2 Without TUCP Delta VA**
    - Predictions from the salvage density model for hardhead include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Whereas at the CVP Jones Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of hardhead for Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at SWP Banks Pumping Plant was greater for all water year types, except in below normal and dry water year types when no fish are expected to be lost (Tables O-108 and O-109). At the SWP Banks Pumping Plant predicted average monthly loss was between 7% and 49% greater in April of wet and above normal water year, respectively (Table O-108).
- **Hardhead: Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for hardhead include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Whereas at the CVP Jones Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of hardhead of Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at the SWP Banks Pumping Plant was greater all water year types, except in below normal and dry water year types when no fish are expected (Tables O-108 and O-109). At the SWP Banks Pumping Plant predicted average monthly loss was between 7% and 49% greater in April of wet and above normal water year, respectively (Table O-108).

<u>Summary</u>

Utilizing the salvage density modeling results, predicted average monthly loss for native minnows was higher for all four components of Alternative 2 for most months and water year types. In most instances higher levels of predicted salvage would occur for all species of native minnow for all four components of Alternative 2 as compared to the No Action Alternative.

O.5.17 Pacific Lamprey

O.5.17.1 Trinity River

Spawning and Egg Incubation

Pacific lamprey typically spawn from March through June, when daily mean water temperatures range from 50–64°F, with peak spawning occurring typically occurring in April and May and when water temperatures are approximately 57–59°F (Stone 2006; Brumo et al. 2009). Redds are typically constructed in gravel and cobble substrates within pool and run tailouts and low gradient riffles (Stone 2006, Brumo et al. 2009). Eggs are deposited in the redd and hatch after approximately 15 days, depending on water temperatures (Meeuwig et al. 2005, Brumo 2006). Egg-sac larvae spend another 15 days in redds before emergence. Water temperatures in excess of 65°F during incubation have been shown to reduce embryo survival (Meeuwig et al. 2005). The effects analysis period for spawning and egg incubation in the Trinity River is March through July.

Potential Changes to Pacific Lamprey Spawning and Egg Incubation from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 2 to flows under the No Action Alternative. Minor differences in monthly average flows between Alternative 2 and the No Action Alternative would occur in November through April of some water year types, with most differences less than 5%. Flows under each phase of Alternative 2 would be very similar, with minor differences among the phases occurring in November through April of some water year types and most differences less than 5%.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be more than 5% lower than the No Action Alternative during the spawning period in March in wet water years (Table O-174). The March flow decreases would occur during Pacific lamprey spawning and egg incubation period. The reduction in flows in wet years would likely be minor in the reduction of spawning habitat and detrimental impacts on egg incubation as flows would still be above 1,876 cfs. Average water temperature in the Trinity River below Lewiston Dam in February and March of wet water years may increase slightly under Alternative 2 With TUCP Without VA compared to the No Action Alternative but would remain below the 50°F upper optimum limit recommended by USEPA (2001, as cited in Carter 2005) from Lewiston Dam to North Fork Trinity River in all water year types to support salmonids. Upper temperature thresholds for Pacific lamprey spawning initiation would not be exceeded and the impacts of Alternative 2 With TUCP Without VA are likely negligible to both Pacific lamprey spawning, and egg incubation.
- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be more than 5% lower than the No Action Alternative during the spawning period in March in wet water years (Table O-175). The March flow decreases would occur during Pacific lamprey spawning and egg incubation period, but flows would still be at or above 1,874 cfs. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey spawning and egg incubation as those described for Alternative 2 With TUCP Without VA.

- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be more than 5% lower than the No Action Alternative during the spawning period in March in wet water years (Table O-176). The March flow decreases would occur during Pacific lamprey spawning and egg incubation period. The reduction in flows in wet years would likely be negligible for spawning habitat and egg incubation as flows would still be above 1,872 cfs. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey spawning and egg incubation as those described for Alternative 2 With TUCP Without VA.
- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative during the spawning period in March in wet water years (Table O-177). The March flow decreases would occur during Pacific lamprey spawning and egg incubation period. The reduction in flows in wet years would likely be negligible for spawning habitat and egg incubation as flows would still be above 1,872 cfs. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey spawning and egg incubation as those described for Alternative 2 With TUCP Without VA.

Ammocoete Rearing and Emigration

After emergence from redds, eyeless Pacific lamprey larvae, known as ammocoetes, settle out of the water column and burrow into fine silt and sand substrates, often containing organic matter. Ammocoetes rear in these habitats for four to 10 years. Water temperature requirements for the life stage are not well described. Ammocoetes have been observed burrowed in substrates in streams with water temperatures up to 80°F (Claire 2004), and upper water temperature tolerances are estimated to be around 83°F (Whitesel and Uh 2023). After Pacific lamprey metamorphose to the macropthalmia stage, individuals migrate to the ocean typically in conjunction with high flow events between fall and spring, but can occur year-round. The effects analysis period for ammocoete rearing is year-round and emigration is primarily fall through spring in the Trinity River

Potential Changes to Pacific Lamprey Ammocoete Rearing and Emigration from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 2 to flows under the No Action Alternative. Minor differences in monthly average flows between Alternative 2 and the No Action Alternative would occur in November through April of some water year types, with most differences less than 5%. Flows under each phase of Alternative 2 would be very similar, with minor differences among the phases occurring in November through April of some water year types and nearly all differences less than 5%.

Average water temperature in the Trinity River below Lewiston Dam in February and March of wet water years may increase slightly under Alternative 2 With TUCP Without VA compared to the No Action Alternative but would remain below the 50°F upper optimum limit recommended by USEPA (2001, as cited in Carter 2005) from Lewiston Dam to North Fork Trinity River in all water year types to support salmonids. Upper temperature thresholds for Pacific lamprey ammocoete rearing and emigration would not be exceeded and the impacts of Alternative 2 With

TUCP Without VA are likely negligible to both Pacific lamprey ammocoete growth rates, and emigration.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (TableO.Trin_Atl2_1). The reduction in flows could have minor impacts in the reduction of rearing habitat, and reduced flows during peak emigration periods in December of below normal years as flows decrease from 931 to 819 cfs. Alternative 2 With TUCP Without VA monthly average flows will have negligible to minor impacts on ammocoete rearing and emigration of Pacific lamprey when compared to the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey ammocoete rearing and emigration as those described for Alternative 2 With TUCP Without VA.
- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (TableO.Trin_Atl2_2). A greater than 5% increase in flow is expected only in February in above normal years. The reduction in flows could have minor impacts in the reduction of rearing habitat, and reduced flows during peak emigration periods in December of below normal years as flows decrease from 931 to 818 cfs. Increases in flow in February are likely to have negligible impacts on ammocoete rearing and emigration, as flows would only increase from 1,194 to 1,257 cfs. Alternative 2 Without TUCP Without VA monthly average flows will have negligible to minor impacts on ammocoete rearing and emigration of Pacific lamprey when compared to the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey ammocoete rearing and emigration as those described for Alternative 2 With TUCP Without VA.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (TableO.Trin_Atl2_3). The reduction in flows could have minor adverse impacts in the reduction of rearing habitat, and reduced flows during peak emigration periods in December of below normal years, as flows decrease from 931 to 788 cfs. Alternative 2 Without TUCP With Delta VA monthly average flows will have negligible to minor adverse impacts on ammocoete rearing and emigration of Pacific lamprey when compared to the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey ammocoete rearing and emigration as those described for Alternative 2 With TUCP Without VA.

- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (TableO.Trin_Atl2_4). A greater than 5% increase in flow is expected only in February in above normal years. The reduction in flows could have minor adverse impacts in the reduction of rearing habitat, and reduced flows during peak emigration periods in December of below normal years as flows decrease from 931 to 819 cfs. Increases in flow in February are likely to have negligible impacts ammocoete rearing and emigration, as flows would only increase from 1,194 to 1,325 cfs. Alternative 2 Without TUCP With Systemwide VA monthly average flows will have negligible to minor impacts on ammocoete rearing and emigration of Pacific lamprey when compared to the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey ammocoete rearing and emigration as those described for Alternative 2 With TUCP Without VA.

Adult Upstream Migration and Holding

Adult Pacific lamprey typically enter freshwater from winter to early summer, but in the Klamath River adults have been reported to enter year-round (Petersen-Lewis 2009, Parker 2018). In general, adult Pacific lampreys have two life history types: ocean maturing where individuals likely spawn several weeks after entering freshwater, and stream maturing where individuals spend one year in freshwater prior to spawning (Clemens et al. 2013, Parker et al. 2019). In general, adult Pacific lamprey hold in interstitial spaces within large cobble and boulders and also in glides, runs, and riffles (Lampman 2011). Water temperature requirements for holding adult Pacific lampreys have not been fully evaluated, but adults have been observed in temperatures ranging from 60 to 84°F (Starcevich et al. 2014). The effects analysis period for adult upstream migration and holding in the Trinity River is year-round.

Potential Changes to Pacific Lamprey Adult Upstream Migration and Holding from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 2 to flows under the No Action Alternative. Differences in monthly average flows between Alternative 2 and the No Action Alternative with greater than 5% reduction would occur in February and March of wet years, November in above normal years, and December in below normal years.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (TableO.Trin_Atl2_1). The reduction in flows in winter would likely have minor adverse impacts on the adult upstream migration as flows would remain above 1,684 cfs in wet years in February and March, and 819 cfs in below normal years in December. Alternative 2 With TUCP Without VA monthly average flows will have minor adverse to negligible impacts on adult upstream migration and holding of Pacific lamprey when

compared to the No Action Alternative. Average water temperature in the Trinity River below Lewiston Dam in February and March of wet water years may increase slightly under Alternative 2 With TUCP Without VA compared to the No Action Alternative but would remain below the 50°F upper optimum limit recommended by USEPA (2001, as cited in Carter 2005) from Lewiston Dam to North Fork Trinity River in all water year types to support salmonids. Upper water temperature thresholds for Pacific lamprey upstream migration and holding would not be exceeded and the impacts of Alternative 2 With TUCP Without VA are likely negligible to both Pacific lamprey upstream migration and holding.

- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (TableO.Trin_Atl2_2). A greater then 5% increase in flow is expected only in February in above normal years. The reduction in flows could have minor adverse impacts on upstream migration, but flows would remain above 1,696 cfs. Increases in flow in February are likely to have negligible impacts on upstream migration and holding, as flows would only increase from 1,194 to 1,257 cfs. Alternative 2 Without TUCP Without VA monthly average flows will have negligible to minor impacts on adult upstream migration and holding of Pacific lamprey when compared to the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey upstream migration and holding as those described for Alternative 2 With TUCP Without VA.

- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (TableO.Trin_Atl2_3). The reduction in flows could have minor adverse impacts on upstream migration and holding habitat, but flows would remain above 1,673 cfs. Alternative 2 Without TUCP With Delta VA monthly average flows will have negligible to minor impacts on adult upstream migration and holding of Pacific lamprey when compared to the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey upstream migration and holding as those described for Alternative 2 With TUCP Without VA.

- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (TableO.Trin_Atl2_4). A greater then 5% increase in flow is expected only in February in above normal years. The reduction in flows could have minor adverse impacts on upstream migration, but flows would remain above 1,693 cfs. Increases in flow in February are likely to have negligible impacts on adult upstream migration and holding, as flows would only increase from 1,194 to 1,325 cfs. Alternative 2 Without TUCP With Systemwide VA monthly average flows will have negligible to minor impacts

on adult upstream migration and holding of Pacific lamprey when compared to the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on Pacific lamprey upstream migration and holding as those described for Alternative 2 With TUCP Without VA.

O.5.17.2 Sacramento River

Spawning and Egg Incubation

Pacific lamprey construct redds in shallow water (about 0.5 to 3.5 feet or 0.15 to 1 meter) gravel habitats in the upper river and spawning occurs from March through July with peak spawning typically occurring in early April (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015). The eggs and pro-larvae incubate for about 1 to 1.5 months. Water flows and temperature impacts on eggs are March-August but are largely April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam for Alternative 2 compared to the No Action Alternative are a mix of increases and decreases (Table O-182 through Table O-189). Impacts on Pacific lamprey spawning are likely to be similarly mixed. Below Red Bluff Diversion Dam would see generally smaller changes in flow values compared to Keswick Dam, with greater increases largely from September through January, and larger decreases found May through August. Flows are expected to generally stay similar to those under the No Action Alternative for most water-year types and months. Below Keswick Dam, flows see more significant increases and decreases compared to the No Action Alternative relative to RBDD. Flow increases below Keswick Dam are generally October through March, while more decreases are found May through September. Overall flow changes at both locations are fairly small compared to the No Action Alternative except for Alternative 2 Without TUCP with systemwide VA, which is expected to increase flows in some water-year types for March and April, during peak spawning, while decreasing flows for many water year types May through August. Pacific lamprey spawning is likely to see mixed and minimal impacts from these flow changes. Compared to the No Action Alternative, most phases of Alternative 2 see very little flow change, and spawning would likely see no impact. Alternative 2 Without TUCP with systemwide VA sees the greatest flow changes compared to the No Action Alternative, but even under this regime flows at both locations are high enough in all months and water-year types that spawning and egg incubation should not see any adverse impacts, while flow increases are likely to have minimal benefits at best.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 295 for Keswick Dam and Table 296 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-112. Table O-112, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were zero month-water year type combinations (0% total combinations during the period, respectively) with favorable results at both Keswick Dam and RBDD (Table O-112). There were zero and one month-water year type combinations (0% and 4.0%, respectively) with unfavorable results at both Keswick Dam and RBDD, respectively. These results suggest that there would be negligible impacts of Alternative 2 With TUCP Without VA on Pacific lamprey spawning and egg incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at both Keswick Dam and RBDD (Table O-112). These results suggest that there would be negligible water temperature-related impacts of Alternative 2 Without TUCP Without VA on Pacific lamprey spawning and egg incubation in the Sacramento River.
- Results for **Alternative 2 Without TUCP Delta VA** and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-112).

Overall, the four phases of Alternative 2 would have similar negligible impacts on water temperature conditions for Pacific lamprey spawning and egg incubation in the Sacramento River (Table O-112).

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have a negligible impact on spawning and egg incubation in the Sacramento River due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey larvae (ammocoetes), after emerging, drift downstream and burrow into fine sediments to rear. Ammocoetes select habitats that are often off-channel, with low flow velocity and shallow depths; therefore, they are vulnerable to stranding by reductions in water level. After 3 or more years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean. Data from rotary screw trapping at sites on the mainstem Sacramento River indicate that emigration of Pacific lamprey peaks from early winter through early summer, but some emigration is observed year-round at both the RBDD and the GCID diversion dam (Hanni et al. 2006).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam for Alternative 2 are a largely unchanged compared to the No Action Alternative, with some small increases and decreases, except for Alternative 2 Without TUCP with systemwide VA (Table O-182 through Table O-189). Impacts on Pacific lamprey ammocoete rearing and emigration are likely to be mixed and slight. Flows under all forms of Alternative 2 are expected to remain high enough that ammocoete rearing, taking place in shallow sediments, should be largely unaffected. Flow increases could have slight benefits, and flow decreases could have slight adverse impacts, but these are expected to be minimal. Juvenile emigration is likely to see similar minimal impacts. Flows are expected to remain high enough during the outmigration period that survival should be unaffected. Overall impacts from Alternative 2 on ammocoete rearing and emigration are expected to be mixed but minimal.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific Lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 298 for Keswick Dam and Table 299 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-113. Table O-113, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results at both Keswick Dam and RBDD (Table O-113). These results suggest that there would be negligible water temperature-related impacts of Alternative 2 With TUCP Without VA on Pacific lamprey ammocoete rearing and emigration in the Sacramento River.
- Results for **Alternative 2 Without TUCP with VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VA** were identical to those for Alternative 2 With TUCP Without VA (Table O-113).

Overall, the four phases of Alternative 2 would have similar negligible impacts on water temperature conditions for Pacific lamprey ammocoete rearing and emigration in the Sacramento River (Table O-113).

Summary

Alternative 2 relative to the No Action Alternative is expected to have a minor beneficial to minor adverse impact on Pacific lamprey spawning and egg incubation in the Sacramento River due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have a negligible impact on Pacific lamprey spawning and egg incubation in the Sacramento River due to differences in water temperature.

O.5.17.3 Clear Creek

Spawning and Egg Incubation

Pacific lamprey usually spawn in Clear Creek from March through July, depending on water temperatures and local conditions such as seasonal flow regimes. The adults construct redds similar to steelhead redds, and eggs incubate for 11 to 30 days, depending on the water temperature, prior to hatching. Although the extent of spawning is unknown, the species spawns in Clear Creek as evidenced by ammocoetes routinely collected in the screw trap at RM 1.7. Impacts from water flows and temperature on eggs are likely felt March-August, and they likely peak in accordance with peak spawning April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in Clear Creek below Whiskeytown Dam under Alternative 2 would see a mix of increases and decreases compared to the No Action Alternative (Table O-218 through Table O-221). Impacts on Pacific lamprey spawning would likely be mostly beneficial across all versions of Alternative 2, as flows are increased for the peak spawning period. However, some adverse impacts could be felt in wet, above normal, and below normal years in February, since flows are projected to decrease compared to the No Action Alternative, which could affect the beginning of the spawning period; a similar adverse impact might be felt at the tail end of the spawning period in June and lasting through the summer months, which are all projected to see flow decreases.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 288 for Clear Creek below Whiskeytown Dam.

Results for the analysis are summarized in Table O-114. Table O-114, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were three month-water year type combinations (12.5% of total combinations during the

period) with favorable results and no combinations (0%) with unfavorable results below Whiskeytown Dam (Table O-114). These results suggest that there would be positive water temperature-related impacts of Alternative 2 With TUCP Without VA on Pacific lamprey spawning and egg incubation in Clear Creek.

- Under **Alternative 2 Without TUCP Without VA** for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were three month-water year type combinations (12.5% of total combinations during the period) with favorable results and no combination (0%) with unfavorable results below Whiskeytown Dam (Table O-114). These results suggest that there would be positive water temperature-related impacts of Alternative 2 Without TUCP Without VA on Pacific lamprey spawning and egg incubation in Clear Creek.
- Under **Alternative 2 Without TUCP Delta VA** for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were four month-water year type combinations (16.7% of total combinations during the period) with favorable results and one combination (4.0%) with unfavorable results below Whiskeytown Dam (Table O-114). These results suggest that there would be positive water temperature-related impacts of Alternative 2 Without TUCP Delta VA on Pacific lamprey spawning and egg incubation in Clear Creek.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were four month-water year type combinations (16.7% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable results below Whiskeytown Dam (Table O-114). These results suggest that there would be positive water temperature-related impacts of Alternative 2 Without TUCP Systemwide VAs on Pacific lamprey spawning and egg incubation in Clear Creek.

Overall, the four phases of Alternative 2 would have similar positive impacts on water temperature conditions for Pacific lamprey spawning and egg incubation in Clear Creek (Table O-114).

<u>Summary</u>

Alternative 2 relative to the No Action Alternative is expected to have moderate beneficial to minor adverse impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have beneficial impacts on Pacific lamprey spawning and egg incubation in Clear creek due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey rearing takes place over a matter of years. Hatched embryos remain in the gravel for up to one more month as gill slits develop. The ammocoetes then spend three to seven years in soft sediments as filter feeders (USFWS 2019). Once ammocoetes have become juveniles, they begin to migrate towards the ocean in spring and possibly early summer. Impacts from water temperature and flow on larval and juveniles are year-round due to their prolonged rearing in their home waters, with spring and summer flows during migratory periods being important as well.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in Clear Creek below Whiskeytown Dam under Alternative 2 would see a mix of increases and decreases compared to the No Action Alternative (Table O-218 through Table O-221). Impacts on ammocoete rearing would likely be mixed, as ammocoetes spend a period of years maturing in sediments. Thus they would be subject to both positive and adverse impacts from the flow increases and decreases that are expected to come with all versions of Alternative 2. Juvenile emigration might see a slight overall positive impact from Alternative 2, as flows are expected to increase during the peak outmigration period over the winter and spring months, with the exception of February for wet, above normal and below normal water years.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific Lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 291 for Clear Creek below Whiskeytown Dam.

Results for the analysis are summarized in Table O-115. Table O-115, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-115). These results suggest that there would be negligible impacts of Alternative 2 With TUCP Without VA on Pacific lamprey ammocoete rearing and emigration in Clear Creek.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those of Alternative 2 With TUCP Without VA (Table O-115).

Overall, the four phases of Alternative 2 would have similar negligible impacts on water temperature conditions for Pacific lamprey ammocoete rearing and emigration in Clear Creek (Table O-115).

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey ammocoete rearing, and minor beneficial impacts on juvenile emigration due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration in Clear Creek due to differences in water temperature.

O.5.17.4 Lower American River

Spawning and Egg Incubation

Hannon and Deason (2008) documented Pacific lamprey spawning in the lower American River from early January to late May, with peak spawning typically occurring in early April. Redds are built in shallow water environments and eggs incubate for several weeks before larvae emerge. Water temperature and flow impacts on eggs are likely January-June, with peak impacts April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the lower American River at H Street and below Nimbus Dam under Alternative 2 will see a mixture of increases and decreases compared to the No Action Alternative (Table O-226 through Table O-233). Impacts on Pacific lamprey spawning would likely be mixed, with some months and water year types seeing flow increases and accompanying positive impacts, and others with flow decreases and accompanying negative impacts. Flow decreases in certain months of critically dry years could have a negative impact on spawning, while flow increases in certain months of dry and critically dry years would likely benefit Pacific lamprey spawning. Impacts during the peak months of April and May are likely to be more positive than negative but depend on water year type.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities during March through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 79 for Hazel Avenue and Table 80 for Watt Avenue.

Results for the analysis are summarized in Table O-116. Table O-116, as described in Section O.4.17.4.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities for Pacific lamprey spawning and egg incubation, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-116). There were three and one month-water year type combinations (12.0% and 4.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Without VA** for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities for Pacific lamprey spawning and egg incubation, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-116). There were two and zero month-water year type combinations (8.0% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

- Under **Alternative 2 Without TUCP Delta VA** for the for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities for Pacific lamprey spawning and egg incubation, there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-116). There were three and zero month-water year type combinations (12.0% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities for Pacific lamprey spawning and egg incubation, there were zero and one month-water year type combinations (0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-116). There were three and zero month-water year type combinations (12.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, the four phases of Alternative 2 would have mostly negative water temperature-related impacts to Pacific lamprey spawning and egg incubation in the lower American River.

Summary

Alternative 2 relative to the No Action Alternative is expected to have beneficial and negative impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have mostly negative impacts on Pacific lamprey spawning and egg incubation in the lower American River due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey ammocoetes rear in the lower American River for all or part of their three to seven freshwater residence. Larvae spend a month maturing to ammocoetes before leaving spawning areas to find suitable rearing habitat, usually shallow, off-channel areas with low flow velocity where they will spend the next several years filter-feeding and maturing to juvenile stage. Once juveniles, they will begin migrating towards the ocean. Data from rotary screw trapping in the nearby Feather River suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006), although some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006) and in other river systems (Moyle 2002).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the lower American River at H Street and below Nimbus Dam under Alternative 2 will see a mixture of increases and decreases compared to the No Action Alternative (Table O-226 through Table O-233). Impacts on Pacific lamprey ammocoete rearing would likely be mixed, as ammocoetes spend a period of several years maturing in sediment and would be present for both flow increases and decreases as months and water years change. Flow decreases in many months of critically dry years are likely to have adverse impacts on ammocoete rearing. Impacts on juvenile emigration would likely be similarly mixed, with

flow increases and decreases forecast for the outmigration period over winter and spring months. Flow decreases in winter months of critically dry years are likely to have adverse impacts on emigration, while increases in some spring months of the same years would likely have benefits.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 48 for Hazel Avenue and Table 50 for Watt Avenue.

Results for the analysis are summarized in Table O-117. Table O-117, as described in Section O.4.17.4.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 72°F upper limit for high survival and low occurrence of developmental abnormalities there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-117). There were zero and one month-water year type combinations (0% and 1.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Without VA** for the 72°F upper limit for high survival and low occurrence of developmental abnormalities there were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-117). There were one and zero month-water year type combinations (1.7% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Delta VA** for the 72°F upper limit for high survival and low occurrence of developmental abnormalities there were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-117). There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 72°F upper limit for high survival and low occurrence of developmental abnormalities there were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-117). There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that there would be negligible water temperature-related impacts to Pacific lamprey ammocoete rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to negative impacts on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Alternative 2 relative to the No Action alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration in the lower American River due to differences in water temperature.

O.5.17.5 Stanislaus River

Spawning and Egg Incubation

Hannon and Deason (2008) have documented Pacific lampreys spawning in the lower American River from early January to late May, with peak spawning typically in early April. Spawning time is presumably similar in the Stanislaus River. Eggs are laid in redds constructed in shallow water, and incubation takes several weeks. Effects from water flows and temperature on eggs are present February-June, likely with a peak April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Stanislaus River at the mouth and below Goodwin Dam under Alternative 2 will see a mix of increases and decreases depending on month and water year type (Table O-234 through Table O-241). The greatest impacts on Pacific lamprey spawning might be felt below Goodwin Dam, where flows see decreases for most water year types during the period of peak spawning in April and May, which could have an adverse impact. However, some flow increases in February could have a slight benefit to the beginning of the spawning period. Impacts would likely not be as strong on spawning near the mouth, where changes in flow are predicted to be smaller in scale than the changes below Goodwin Dam. Overall impacts of flow changes on Pacific lamprey spawning and egg incubation are likely to be mixed, but slightly more adverse than beneficial.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities during April through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 62 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-118. Table O-118, as described in Section O.4.17.5, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities of Pacific lamprey, there were no month-water year type combinations (0.0%) with favorable or unfavorable results at both Orange Blossom Bridge (Table O-118).

- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-118).

Overall, the four phases of Alternative 2 would have negligible water temperature related impacts on Pacific lamprey spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor adverse to minor beneficial impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey spawning and egg incubation in the Stanislaus River due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey ammocoetes are expected to rear in the Stanislaus River for all or part of their 3- to 7-year freshwater residence. Larvae usually spend a month in their spawning areas before becoming ammocoetes and moving to rearing habitat in shallow, off-channel areas. After several years, they become juveniles and migrate out to the ocean. Data from rotary screw trapping in the nearby Mokelumne and Tuolumne Rivers suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006). Catches of juvenile Pacific lampreys in trawl surveys of the mainstem San Joaquin River, near the mouth of the Stanislaus River at Mossdale, occurred during winter and spring. Some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Stanislaus River at the mouth and below Goodwin Dam under Alternative 2 will see a mix of increases and decreases depending on month and water year type (Table O-234 through Table O-241). Impacts on Pacific lamprey ammocoete rearing are likely to be mixed, as flow decreases in wetter years might be balanced by flow increases in some months of drier years. As ammocoete rearing takes place over several years, ammocoetes would experience both flow increases and decreases under Alternative 2. Impacts on juvenile outmigration are likely to be similarly mixed, with some months during the winter-early summer outmigration period having flow increases and likely beneficial impacts, and others having flow decreases and accompanying adverse impacts.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 63 for Orange Blossom Bridge and Table 64 for the Stanislaus River above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-119. Table O-119, as described in Section O.4.17.5, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific lamprey, there were no month-water year type combinations (0.0%) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-119). There were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-119).

Overall, the four phases of Alternative 2 would have negligible water temperature related impacts on Pacific lamprey ammocoete rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Alternative 2 and the No Action Alternative are expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration in the Stanislaus River due to differences in water temperature.

O.5.17.6 San Joaquin River

Ammocoete Rearing and Emigration

Pacific lamprey larvae, once emerged, spend roughly a month in spawning areas before becoming ammocoetes and moving to rearing habitat in shallow, off-channel waters with low flow velocity, where they will spend the following several years (roughly three to seven) maturing to the juvenile stage. Once individuals mature to juveniles, they begin a migration towards the ocean. Midwater trawl surveys in the San Joaquin River suggest that peak ammocoete out-migration occurs in January and February (Hanni et al. 2006). Ammocoetes are vulnerable to habitat loss due to the nature of their rearing habitat.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 models predict that flows for the San Joaquin River at Vernalis under Alternative 2 would see small changes, both positive and negative depending on month and water year type, compared to the No Action Alternative (Table O-242 through Table O-245). These flow changes are expected to be rather small, so impacts on ammocoete rearing in Pacific lamprey, which lasts for a period of several years, are likely to be minimal. Increased flows during summer months of critically dry years would likely be beneficial, but overall Alternative 2 is not likely to have

much impact on ammocoete rearing. Flow changes for winter and spring months are small to negligible, so impacts on juvenile emigration would likely be the same.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on Pacific lamprey in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

Summary

Alternative 2 relative to the No Action Alternative are expected to have minor beneficial impacts on Pacific lamprey ammocoete rearing and negligible impacts on juvenile emigration in the San Joaquin River due to differences in flow. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

O.5.17.7 Bay-Delta

Some Pacific lamprey ammocoetes likely spend part of their extended (3 to 7 years) freshwater residence rearing in the Delta, particularly in the upstream, freshwater portions (California Department of Water Resources et al. 2013). Ammocoetes are present year-round in all of the regions (California Department of Water Resources et al. 2013). Data from the Fall Midwater Trawl Survey in the lower Sacramento and San Joaquin Rivers and Suisun Bay suggest that peak out-migration of Pacific lamprey through the Delta coincides with high-flow events from fall through spring (Hanni et al. 2006).Water temperature and flows affect resident ammocoetes year round and migrating juveniles fall-spring. Duration of estuarine adult migration and holding in the San Francisco Estuary is poorly understood, but some evidence suggests they may migrate as early as the fall and throughout the spawning season until late June (Moyle et al. 2015).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Sacramento River at Rio Vista under Alternative 2 would see a mix of increases and decreases compared to the No Action Alternative (Table O-214 through Table O-217). For impacts in the southern Delta, see the San Joaquin River section above, which discusses flow at Vernalis. Under Alternative 2, flows at Rio Vista are expected to be a mixture of increases and decreases compared to the No Action Alternative. Alternative 2 Without TUCP with systemwide VA is the exception, with flows mostly increasing in April and May. Impacts on Pacific lamprey ammocoete rearing are expected to be negligible, as flows are likely adequate for rearing in the sandy substrates. Changes in flows under the four phases of Alternative 2 are likely to have minor beneficial impact on juvenile emigration and adult migration in critically dry water year types, as flows are expected to increase in the spring and summer.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial impacts on Pacific lamprey adult migration and juvenile emigration in critically dry water year types due to differences in flow. Impacts on ammocoete rearing are expected to be negligible.

Potential Changes to Entrainment of Pacific Lamprey

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have impacts on Pacific lamprey entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for Pacific lamprey include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Pacific lamprey of Alternative 2 With TUCP Without VA compared to the No Action Alternative at CVP Jones Pumping Plant were similar all water year types (Tables O-120 and O-121). At the CVP Jones Pumping Plant predicted average monthly loss was up to 2% greater for December through September of critically dry water year types and as low as -2% March through August of dry water years (Table O-121). Historical loss of Pacific lamprey is infrequent; this is a driver of low values of predicted loss.
- **Alternative 2 Without TUCP Without VA**
    - Predictions from the salvage density model for Pacific lamprey include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Pacific lamprey of Alternative 2 Without TUCP Without VA compared to the No Action Alternative at CVP Jones Pumping Plant were similar all water year types, except December through September of critically dry water years when it was greater (Tables O-120 and O-121). At the CVP Jones Pumping Plant predicted average monthly loss was up to 11% greater for December through September of critically dry water year types and as low as -2% March through August of dry water years (Table O-121). Historical loss of Pacific lamprey is infrequent; this is a driver of low values of predicted loss.

- **Alternative 2 Without TUCP Delta VA**
    - Predictions from the salvage density model for Pacific lamprey include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Pacific lamprey of Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at CVP Jones Pumping Plant were lower below normal, above normal, and dry water year types (August through , except December through September of critically dry water years when it was greater (Tables O-120 and O-121). At the CVP Jones Pumping Plant predicted average monthly loss was up to 11% greater for December through September of critically dry water year types and as low as -2% March through August of dry water years (Table O-121). Historical loss of Pacific lamprey is infrequent; this is a driver of low values of predicted loss.
- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for Pacific lamprey include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Pacific lamprey of Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at the CVP Jones Pumping Plant were greater critically dry year types and similar or lower all other water year types (Tables O-120 and O-121). At the CVP Jones Pumping Plant predicted average monthly loss was up to 9% greater for December through August of critically dry water year types and as low as -18 % for January through October of below normal water year types (Table O-121). Historical loss of Pacific lamprey is infrequent; this is a driver of low values of predicted loss.

Summary

Differences in exports between the four phases of Alternative 2 and the No Action Alternative are expected to have generally beneficial impacts on the entrainment of Pacific lamprey at CVP Jones Pumping Plant, but the species is infrequent at the facility. No impacts at the SWP Banks Pumping Plant are expected.

O.5.18 Western River Lamprey

O.5.18.1 Sacramento River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam for Alternative 2 compared to the No Action Alternative are a mix of increases and decreases (Table O-182 through Table O-189). Impacts on western river lamprey spawning are likely to be similarly mixed. Below Red Bluff Diversion Dam would see generally smaller changes in flow values compared to Keswick Dam, with greater increases largely from October through April, and larger decreases found May through September. Flows are expected to generally stay similar to those under the No Action Alternative for most water-year types and months. Below Keswick Dam, flows see more significant increases and decreases compared to the No Action Alternative relative to RBDD. Flow increases below Keswick Dam are generally October through April, while more decreases are found May through September. Overall flow changes at both locations are fairly small compared to the No Action Alternative except for Alternative 2 Without TUCP with systemwide VA, which is expected to increase flows in some water-year types for March and April, during peak spawning, while decreasing flows for many water-year types May through September. Western river lamprey spawning is likely to see mixed minimal impacts from these flow changes. Compared to the No Action Alternative, most increments of Alternative 2 see very little flow change, and spawning would likely see no impact. Alternative 2 Without TUCP with systemwide VA sees the greatest flow changes compared to the No Action Alternative, but even under this regime flows at both locations are high enough in all months and water-year types that spawning and egg incubation should not see any adverse impacts, while flow increases are likely to have minimal benefits at best.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 301 for Keswick Dam and Table 302 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-122. Table O-122, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities, there were three and zero month-water year type combinations (10.0% and 0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-122). There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. These results suggest that there would be positive water temperature-related impacts of Alternative 2 With TUCP Without VA on western river lamprey spawning and egg incubation in the Sacramento River.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA, and Alternative 2 without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP without VA (Table O-122).

Overall, the four phases of Alternative 2 would have similar positive impacts on water temperature conditions for western river lamprey spawning and egg incubation in the Sacramento River (Table O-122).

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on western river lamprey spawning and egg incubation due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have beneficial impacts on western river lamprey spawning and egg incubation in the Sacramento River due to differences in water temperature.

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam for Alternative 2 are a largely unchanged compared to the No Action Alternative, with some small increases and decreases, except for Alternative 2 Without TUCP with systemwide VA (Table O-182 through Table O-189). Impacts on western river lamprey ammocoete rearing and emigration are likely to be mixed and slight. Flows under all forms of Alternative 2 are expected to remain high enough that ammocoete rearing, taking place in

shallow sediments, should be largely unaffected. Flow increases could have slight benefits, and flow decreases could have slight adverse impacts, but these are expected to be minimal due to robust flow values and to the fact that changes relative to the No Action Alternative are minor. Juvenile emigration is likely to see similar minimal impacts. Flows are expected to remain high enough during the outmigration period that survival should be unaffected. Overall impacts from Alternative 2 on western river lamprey ammocoete rearing and emigration are expected to be mixed but minimal.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for western river lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Keswick Dam and Table 305 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-123. Table O-123, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results at both Keswick Dam and RBDD (Table O-123). These results suggest that there would be negligible water temperature-related impacts of Alternative 2 With TUCP Without VA on western river lamprey ammocoete rearing and emigration in the Sacramento River.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-123).

Overall, the four phases of Alternative 2 would have similar negligible impacts on water temperature conditions for western river lamprey ammocoete rearing and emigration in the Sacramento River (Table O-123).

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on western river lamprey ammocoete rearing and emigration due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on western river lamprey ammocoete rearing and emigration in the Sacramento River due to differences in water temperature.

O.5.18.2 Lower American River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April–May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 2 are a mix of increases and decreases compared to the No Action Alternative (Table O-226 through Table O-233). Impacts on western river lamprey spawning are likely mixed as well. The greatest impacts on spawning might be in critically dry years, which see flow increases in March, April, and June for all versions of Alternative 2 except with TUCP Without VA. Increased flows during these months in critically dry years would likely be beneficial to lamprey spawning, which takes place March through August. However, these increases would come with flow decreases in May, which could have an adverse impact on spawning in a peak month for western river lamprey. Flows also decrease in some summer months (depending on water year type), which could have an adverse impact on spawning towards the end of the spawning season. Overall impacts on spawning are likely to be mixed, with flow increases providing benefits in some months and negative impacts from flow decreases in others.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in western river lamprey during February through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 83 for Hazel Avenue and Table 84 for Watt Avenue.

Results for the analysis are summarized in Table O-124. Table O-124, as described in Section O.4.18.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in western river lamprey spawning and egg incubation, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-124). There were four and one month-water year type combinations (13.3% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

- Under **Alternative 2 Without TUCP Without VA** for the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in western river lamprey spawning and egg incubation, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-124). There were two and zero month-water year type combinations (6.7% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Delta VA** for the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in western river lamprey spawning and egg incubation, there were zero and one month-water year type combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-124). There were four and zero month-water year type combinations (13.3% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in western river lamprey spawning and egg incubation, there were zero and one month-water year type combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-124). There were three and one month-water year type combinations (10.0% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, the four phases of Alternative 2 would have mostly negative water temperature-related impacts to western river lamprey spawning and egg incubation lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on western river lamprey spawning and egg incubation due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have adverse impacts on western river lamprey spawning and egg incubation in the lower American River due to differences in water temperature.

Ammocoete Rearing and Emigration

Western River lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and water temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 2 are a mix of increases and decreases compared to the No Action Alternative (Table O-226 through Table O-233). Impacts on western river lamprey ammocoete rearing are likely to be mixed as well. As rearing takes place over a period of several years, ammocoetes would experience the range of impacts from changes in flow, likely over multiple water year types. The greatest impacts on rearing would likely be in critically dry years, which see increases in a handful of months but decreases during some of the driest months, which could have an adverse impact on ammocoete success and survival. Effects of flow changes on western river lamprey juvenile emigration are likely to be mixed. Flows during the winter-early summer emigration period are largely unchanged compared to the No Action Alternative, with the exception of critically dry years which see a range of increases and decreases during this time. Flows are higher in these years later in the emigration window, and lower in the first few months. Overall impacts on emigration are likely to be mixed.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities in western river lamprey year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 85 for Hazel Avenue and Table 86 for Watt Avenue.

Results for the analysis are summarized in Table O-125. Table O-125, as described in Section O.4.18.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 72°F upper limit for high survival and low occurrence of developmental abnormalities in western river lamprey ammocoete rearing and emigration, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-125). There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those presented for Alternative 2 With TUCP Without VA (Table O-125).

These results suggest that the Alternative 2 combinations would have negligible water temperature-related impacts to western river lamprey ammocoete rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on western river lamprey ammocoete rearing and emigration due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on western river lamprey ammocoete rearing and emigration in the lower American River due to differences in water temperature.

O.5.18.3 Stanislaus River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Stanislaus River at the mouth and below Goodwin Dam for Alternative 2 are a mix of increases and decreases compared to the No Action Alternative (Table O-234 through Table O-241). Effects on western river lamprey spawning are likely to be mixed as well. Flow decreases in April for most water year types would likely have as adverse impact on spawning, as this would be during the peak spawning period. Wet, above normal, and below normal years see flow decreases in June, which would also have an adverse impact; these are mostly smaller than the decreases in April. Increases in flows during June, July, and August in critically dry years would be beneficial to spawning, as this would likely increase spawning success and egg survival in months where flows are among the lowest under the No Action Alternative. Overall impacts on spawning are mixed depending on water year type, but outside of critically dry years these impacts are likely more negative than positive.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in western river lamprey during February through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 65 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-126. Table O-126, as described in Section O.4.18.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities of western river lamprey, there were zero month-water year type combinations (0.0%) with favorable results and one combination (3.3%) with unfavorable results at both Orange Blossom Bridge (Table O-126).
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-126).

Overall, the four phases of Alternative 2 would have negligible water temperature related impacts on western river lamprey spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to moderate adverse impacts on western river lamprey spawning and egg incubation due to differences in flow. Alternative 2 and the No Action Alternative is expected to have negligible impacts on western river lamprey spawning and egg incubation in the Stanislaus River due to differences in water temperature.

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Stanislaus River at the mouth and below Goodwin Dam for Alternative 2 are a mix of increases and decreases compared to the No Action Alternative (Table O-234 through Table O-241). Effects on western river lamprey ammocoete rearing are likely to be mixed as well. Flow increases in summer months of critically dry would likely have a positive impact on rearing, increasing ammocoete survival, but decreases in some water year types for spring months would likely have an adverse impact. Effects overall are likely to be mixed positive and negative, as rearing takes place over several years and ammococtes would experience the impacts of flow increases and decreases. Effects of flow changes on western river lamprey juvenile emigration are also likely mixed. Flows mostly increase in February, which is within the primary outmigration period, but decreases in some water year types March-June could have negative impacts on the second half of this period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities in western river lamprey year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 66 for Orange Blossom Bridge and Table 67 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-127. Table O-127, as described in Section O.4.18.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 72°F upper limit for high survival and low occurrence of developmental abnormalities for western river lamprey, there were no month-water year type combinations (0.0%) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-127). There were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-127).

Overall, the four phases of Alternative 2 would have negligible water temperature related impacts on western river lamprey ammocoete rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Alternative 2 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on western river lamprey ammocoete rearing and emigration due to differences in flow. Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on western River lamprey ammocoete rearing and emigration in the Stanislaus River due to differences in water temperature.

O.5.18.4 San Joaquin River

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 estimates for monthly flows in the San Joaquin River at Vernalis for Alternative 2 are largely unchanged compared to the No Action Alternative (Table O-242 through Table O-245). Impacts on western river lamprey ammocoete rearing are likely to be slight, but beneficial. The greatest change in flows is during summer months in critically dry years, which would be beneficial to ammocoete rearing and survival when conditions are at their most unfavorable. Otherwise, flows are almost unchanged compared to the No Action Alternative, and are expected to have little impact on ammocoete rearing. Impacts on juvenile emigration are also negligible, as flows are basically unchanged for all water year types during the outmigration period of winter through early summer.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on western river lamprey in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 2 relative to the No Action Alternative is expected to have negligible to minor beneficial impacts on western river lamprey ammocoete rearing and emigration in the San Joaquin River due to differences in flow. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.5.18.5 Bay-Delta

The Sacramento and San Joaquin River basins are at the southern edge of the range for western river lamprey (Moyle et al. 2009). While their population abundance is poorly understood, they are frequently caught in the Delta Juvenile Fish Monitoring Program in the winter months through trawls at Sherwood Harbor, Mossdale, and Chipps Island (Interagency Ecological Program et al. 2022). Ammocoetes spend an unknown amount of time as ammocoetes (likely 3-5 years) in silt-sand backwater eddies and have been documented during dredging studies in the Delta (Lamprey Technical Workgroup 2021; Moyle et al. 2015). Adults typically start their migration back into their natal habitats in the fall.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Bay-Delta under the four phases of Alternative 2 would see a mix of increases and decreases compared to the No Action Alternative (Table O-214 through Table O-217). For impacts in the southern Delta, see the San Joaquin River section above, which discusses flow at Vernalis. Under the four phases of Alternative 2, flows at Rio Vista are expected to be a mixture of increases and decreases compared to the No Action Alternative. Alternative 2 Without TUCP with systemwide VA is the exception, with flows mostly increasing in April and May. Similar to Pacific lamprey, impacts on western river lamprey ammocoete rearing are expected to be negligible. Increased flow at Rio Vista in spring and summer of critically dry years could have a minor beneficial impact on juvenile emigration.

Impacts on adult migration are likely to be negligible, with no larger trend in flows during the fall of critically dry water years.

Summary

Alternative 2 relative to the No Action Alternative are expected to have minor beneficial impacts on western river lamprey juvenile emigration in critically dry water year types and negligible impacts on adult migration due to differences in flow. Impacts on ammocoete rearing are expected to be negligible.

Potential Changes to Entrainment of Western River Lamprey

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have impacts on western river lamprey entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for western river lamprey include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of western river lamprey of Alternative 2 With TUCP Without VA compared to the No Action Alternative at CVP Jones Pumping Plant were similar most water year types, except in dry water year types when no fish are expected and February through March of critically dry water years when it would decrease up to 5% (Table O-128 and Table O-129). Historic loss of western river lamprey is infrequent; this is a driver of low values of predicted loss.
- **Alternative 2 Without TUCP Without VA**
    - Predictions from the salvage density model for western river lamprey include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of western river lamprey of Alternative 2 Without TUCP Without VA compared to the No Action Alternative at CVP Jones Pumping Plant were similar most water year types, except in dry water year types when no fish are expected and February through March of critically dry water years when it would decrease up to 6% (Table O-128 and Table O-129).

- **Alternative 2 Without TUCP Delta VA**
    - Predictions from the salvage density model for western river lamprey include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of western river lamprey of Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at CVP Jones Pumping Plant were similar most water year types, except in dry water year types when no fish are expected and February through March of critically dry water years when it would decrease up to 9% (Table O-128 and Table O-129).
- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for western river lamprey include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of western river lamprey of Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at the CVP Jones Pumping Plant were similar most water year types, except in dry water year types when no fish are expected and February through March of critically dry water years when it would decrease up to 9% (Table O-128 and Table O-129).

Summary

Differences in exports between the four phases of Alternative 2 and the No Action Alternative are expected to have generally beneficial impacts on the entrainment of Western river lamprey at CVP Jones Pumping Plant during critically dry water years, but the species is infrequent at the facility. No impacts at the SWP Banks Pumping Plant are expected.

O.5.19 Striped Bass

O.5.19.1 Sacramento River

Spawning and Egg Incubation

It is believed that striped bass do not spawn or rear in the Sacramento River upstream of RBDD (Tehama-Colusa Canal Authority 2008). Most spawning in the Sacramento River occurs in the lower river between Colusa and the confluence of the Sacramento and Feather Rivers (Moyle 2002). About one-half to two-thirds of adults spawn in the Sacramento River and the remainder spawn in the Delta (Leet et al. 2001). After spawning, most adult striped bass move downstream into brackish and salt water for summer and fall (Moyle 2002).

Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows at Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤6%) increase or decrease is estimated April through June (Alternative 2 With TUCP with Systemwide VA at Red Bluff Diversion Dam). Generally, increases are expected to occur in April and decreases June. However, changes are expected to be minor and suggests habitat will largely remain similar to the No Action Alternative (Table O-186 through Table O-189, Table O-190 through Table O-193, and Table O-194 through Table O-197).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 68°F optimal water temperature range for spawning, embryo incubation and initial rearing for striped bass during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 317 for Butte City.

Results for the analysis are summarized in Table O-130. Table O-130, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 59°F to 68°F optimal water temperature range, there were two month-water year type combinations (13.3% of total combinations during the period) with favorable results at Butte City (Table O-130). There were no combinations (0%) with unfavorable results at Butte City. These results suggest that there would be positive impacts from Alternative 2 With TUCP Without VA on striped bass spawning and egg incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 59°F to 68°F optimal water temperature range, there were three month-water year type combinations (20.0% of total combinations during the period) with favorable results at Butte City (Table O-130). There were no combinations (0%) with unfavorable results at Butte City. These results suggest that there would be positive impacts from Alternative 2 Without TUCP Without VA on striped bass spawning and egg incubation in the Sacramento River.
- Under **Alternative 2 Without TUCP Delta VA** for the 59°F to 68°F optimal water temperature range, there was one month-water year type combination (6.7% of total combinations during the period) with favorable results at Butte City (Table O-130). These results suggest that there would be positive impacts from Alternative 2 Without TUCP Delta VA on striped bass spawning and egg incubation in the Sacramento River.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 59°F to 68°F optimal water temperature range, there were two month-water year type combinations (13.3% of total combinations during the period) with favorable results at Butte City (Table O-130). There was one combination (6.7%) with unfavorable results at Butte City. These results suggest that there would be positive water temperature-related impacts and negligible negative impacts from Alternative 2 Without TUCP Systemwide VA on striped bass spawning and egg incubation in the Sacramento River.

Overall, the four phases of Alternative 2 would have similar positive impacts on water temperature conditions for striped bass spawning and egg incubation in the Sacramento River (Table O-130).

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative for CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will largely remain similar with adverse impacts in June. The water temperature analysis indicates that there would be beneficial effects of all phases of Alternative 2 on striped bass spawning and egg incubation. Overall, these results suggest that there would be minor adverse impacts from flow on spawning habitat and generally beneficial water temperature-related impacts on striped bass spawning and egg incubation in the Sacramento River under Alternative 2.

Larval and Juvenile Rearing and Emigration

During this early period the embryos and larvae in the Sacramento River are carried into the Delta and Suisun Bay (Moyle 2002). YOY striped bass distribute themselves in accordance with the estuarine salinity gradient (Kimmerer 2002a; Feyrer et al. 2007), indicating that salinity is a major factor affecting their habitat use and geographic distributions. Kimmerer (2002a) found that distributions of fish species, including striped bass, substantially overlapped with the low-salinity zone. Older individuals are increasingly flexible about their distribution relative to salinity (Moyle 2002). Statistically significant correlations between indices of age-0 abundance or survival in the San Francisco Estuary and Delta have been found with Delta outflow (which can be approximated by X2, the distance in km from the Golden Gate Bridge at which bottom salinity is 2 psu) (e.g., Kimmerer et al. 2009; Mac Nally et al. 2010), with evidence for greater extent of habitat as the mechanism (Kimmerer et al. 2009). However, subsequent density-dependent survival after the first summer dampens the effects of flow on subsequent recruitment (Kimmerer et al. 2000).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows at Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤5%) increase and/or decrease is estimated most months except June (Alternative 2 With TUCP with Systemwide VA at Red Bluff Diversion Dam) when a slight (5%) decrease occurs. This suggests habitat will largely remain similar to the No Action Alternative (Table O-186 through Table O-189, Table O-190 through Table O-193, and Table O-194 through Table O-197).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F range of optimal temperatures for larvae, fry, and juvenile rearing and emigration year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 318 for Butte City.

Results for the analysis are summarized in Table O-131. Table O-131, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 61°F to 71°F optimal water temperature range for larvae, fry, and juvenile rearing and emigration, there were zero month-water year type combination (0% of total combinations during the period) with favorable results and two combinations (3.3%) with unfavorable results at Butte City (Table O-131). These results suggest that there would be negligible negative water temperature-related impacts from Alternative 2 With TUCP Without VA on striped bass larvae, fry, and juvenile rearing and emigration in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 61°F to 71°F optimal water temperature range for larvae, fry, and juvenile rearing and emigration, there were no month-water year type combinations (0.0% of total combinations during the period) with favorable results at Butte City (Table O-131). There was one combination (1.7%) with unfavorable results at Butte City. These results suggest that there would be negligible negative water temperature-related effects of Alternative 2 Without TUCP Without VA on striped bass larvae, fry, and juvenile rearing and emigration in the Sacramento River.
- Results for **Alternative 2 without TUCP Delta TUCP VA** and **Alternative 2 without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-131).

Overall, the four phases of Alternative 2 would have negligible negative impacts on water temperature conditions for striped bass larvae, fry, and juvenile rearing and emigration in the Sacramento River (Table O-131).

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative for CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will largely remain similar, except June under Alternative 2 With TUCP with Systemwide VA which had slight adverse impact. The water temperature analysis indicates that all phases of Alternative 2 would cause negligible negative impacts to striped bass larvae, fry, and juvenile rearing and emigration. Overall, these results suggest that there would be minor adverse flow impacts and minor adverse water temperature impacts on striped bass larvae, fry, and juvenile rearing and emigration in the Sacramento River under Alternative 2.

O.5.19.2 Lower American River

Adults

Striped bass are present in the lower American River throughout the year, with the greatest abundance in summer (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam, and at H Street indicate that minor (≤ 5%) increase and/or decrease is estimated for most months except April (Nimbus Dam and H street) under Alternative 2 With TUCP with Systemwide VA when a slight (6-7%) increase occurs (Table O-226 through Table O-229 and Table O-230 through Table O-233). These results suggest flows will remain similar most months of the year, except April which would have slight increase in flow.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F stress initiation value for adult striped bass year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 93 for Hazel Avenue and Table 94 for Watt Avenue.

Results for the analysis are summarized in Table O-132. Table O-132, as described in Section O.4.19.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- For the 77°F stress initiation water temperature value for adult striped bass under **Alternative 2 With TUCP Without VA**, there were zero month-water combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-132). There were also zero month-water combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those presented with Alternative 2 With TUCP Without VA (Table O-132).

These results suggest that the Alternative 2 combinations would have negligible water temperature-related impacts on adult striped bass in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will remain largely similar, except one to two months out of the year when slight beneficial and/or adverse impacts are expected. The optimal water temperature range modeling estimates indicate there are no combinations with beneficial or adverse impacts at Butte City. These results suggest that there would be negligible impacts from flow on adult habitat extent and negligible water temperature-related impacts on adult striped bass in the lower American River at Hazel Avenue and Watt Avenue under Alternative 2.

Juvenile Rearing

Although the occurrence of spawning in the lower American River is uncertain, the river is believed to serve as a nursery area for YOY and subadult striped bass (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam, and at H Street indicate that a minor (≤ 5%) increase and/or decrease is estimated for most months except April (Nimbus Dam and H street) under Alternative 2 With TUCP with Systemwide VA when a slight (6-7%) increase occurs(Table O-226 through Table O-229 and Table O-230 through Table O-233). These results suggest flows will remain similar most months of the year, except April which would have slight increases in flow.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 95 for Hazel Avenue and Table 96 for Watt Avenue.

Results for the analysis are summarized in Table O-133. Table O-133, as described in Section O.4.19.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 61°F to 71°F optimal range for juvenile striped bass, there were zero month-water combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-133). There were one and five month-water combinations (1.7% and 8.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

- Under **Alternative 2 Without TUCP Without VA** for the 61°F to 71°F optimal range for juvenile striped bass, there were zero and two month-water combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-133). There were three and four month-water combinations (5.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Delta VA** for the 61°F to 71°F optimal range for juvenile striped bass, there were zero and two month-water combinations (0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-133). There were two month-water combinations (3.3%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 61°F to 71°F optimal range for juvenile striped bass, there were 0 month-water combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-133). There were one and four month-water combinations (1.7% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP Delta VA would have similar negligible negative water temperature-related impacts on striped bass juvenile rearing in the lower American River. Effects of Alternative 2 Without TUCP Systemwide VAs would be more negative than the other phases.

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will largely remain similar, except one to two months out of the year with slight beneficial and/or adverse impacts. The optimal water temperature range modeling estimates indicate adverse effects at Hazel Avenue and Watt Avenue in the lower American River under most phases of Alternative 2. Overall, these results suggest negligible impacts from flow, as they would be generally similar to the No Action Alternative, and minor adverse water temperature impacts on striped bass juvenile rearing in the lower American River at Hazel Avenue and Watt Avenue under Alternative 2.

O.5.19.3 Stanislaus River

Spawning and Egg Incubation

Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. These adult fish were observed in all habitats (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about three feet tall in the area (U.S. Fish and Wildlife Service 2002).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows vary between minor (≤ 1%) to slight (≤ 8%) decreases estimated at the Stanislaus River April through June (Table O-234 through Table O-237 and Table O-238 through Table O-241). At Goodwin Dam, slight (up to 8%) decreases are expected. At the mouth, on average minor (up to 3%) decreases are expected. These results suggest averaged flows may be anticipated to have minor adverse impacts on striped bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 59°F- 68°F optimal range of water temperature for spawning, embryo incubation, and initial rearing of striped bass for April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 70 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-134. Table O-134, as described in Section O.4.19.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 59°F- 68°F optimal range of water temperature for spawning, embryo incubation, and initial rearing of striped bass, there was one month-water year type combination (6.7%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-134).
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-134).

Overall, the four phases of Alternative 2 would have minor positive water temperature-related impacts on striped bass spawning, embryo incubation, and initial rearing in the Stanislaus River at Orange Blossom Bridge.

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests flows may have minor adverse impacts on striped bass. The optimal water temperature range modeling estimates indicate a 6.7% month-water year type combination with beneficial results and no combinations with adverse results at Orange Blossom Bridge. Overall, these results suggest minor adverse flow and minor beneficial water temperature-related impacts to striped bass spawning and egg incubation in the Stanislaus River at Goodwin Dam and the mouth under all phases of Alternative 2.

Larval and Juvenile Rearing and Emigration

Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (U.S. Fish and Wildlife Service 2002).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows vary between minor (≤1%) to slight (≤ 13%) increases and minor (≤ 1%) to slight (≤ 8%) decreases estimated at Goodwin Dam and mouth of the Stanislaus River; increases above 5% in averaged flow are expected four and two of the months at Goodwin Dam and the mouth (respectively) and decreases above 5% one month out of the year at Goodwin Dam (Table O-234 through Table O-237 and Table O-238 through Table O-241). At Goodwin Dam, slight (≤ 13%) increases are expected an average of 4 months (December, February, July, and August) and a slight (8%) decrease in April; the remaining five months would generally have minor (≤ 5%) increases and decreases in flow. At the mouth, on average slight (≤ 10%) increases are expected in August and September; the remaining 10 months, increases and decreases are minor (≤ 4%). These results suggest averaged flows may be anticipated to have generally beneficial impacts on striped bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 71 for Orange Blossom Bridge and Table 72 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-135. Table O-135, as described in Section O.4.19.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing there were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-135). There were zero and three month-water year type combinations (0.0% and 5.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.
- Under **Alternative 2 Without TUCP Without VA** for the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing there were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-135). There were zero and four month-water year type combinations (0.0% and 6.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

- Under **Alternative 2 Without TUCP Delta VA** and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-135).

Overall, the four phases of Alternative 2 would have minor negative water temperature-related impacts on striped bass juvenile rearing in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests flows may have generally beneficial impacts on striped bass. The optimal water temperature range modeling estimated that Alternative 2 would likely have minor water temperature-related effects on juvenile striped bass, with Alternative 2 without TUCP without VA having slightly more adverse impacts than other phases of Alternative 2. Overall, these results suggest that there would be minor beneficial flow impacts and minor adverse water temperature-related impacts on striped bass juvenile rearing and emigration in the Stanislaus River above the confluence with the San Joaquin River.

O.5.19.4 San Joaquin River

Striped bass are regularly found in San Joaquin River tributaries, including in lower mainstem deep pools of the Stanislaus and Tuolumne Rivers (e.g., Anderson et al. 2007). Ainsley et al. (2013) reported that striped bass were collected at two locations between the Head of the Old River and the mouth of the Stanislaus River on the mainstem San Joaquin River in May. In the San Joaquin River outflow is balanced by tidal currents, so that embryos and larvae stay suspended in the same general area in which spawning took place. Essentially, larval bass from both rivers are most abundant where salt and fresh water meet. Thus, when they begin to feed, they are concentrated in the most productive portions of the entire estuary. Larval growth and survival rates are also highest in areas of brackish water, presumably because of reduced energy costs for osmoregulation (Moyle 2002).

Potential Changes to Striped Bass from Seasonal Operations

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows vary between minor (≤ 3%) increases and/or decreases are estimated at Vernalis most months; however, minor (6%) to substantial (≤ 34%) increases are generally expected June through September of critically dry water years (Table O-242 through Table O-245). These differences suggest averaged flows estimates will largely be similar to the No Action Alternative under all phases of Alternative 2, except in June through September of dry water years when flow increases occur.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on striped bass in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 suggest mean monthly flow will largely be similar; however, there may be beneficial impacts on striped bass expected during June through September of dry water years. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.5.19.5 Bay-Delta

Striped bass use the Delta as a migratory route and for rearing and seasonal foraging. Striped bass spend the majority of their lives in salt water, returning to freshwater to spawn. Adult striped bass spend about six to nine months of the year in San Francisco and San Pablo Bays (Hassler 1988). Striped bass also use deeper areas of many of the larger channels in the Delta, in addition to large embayments such as Suisun Bay.

Spawning occurs in spring, primarily in the Sacramento River between Sacramento and Colusa and in the San Joaquin River between Antioch and Venice Island (Farley 1966). Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all striped bass eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows vary between minor (≤5%) to substantial (≤ 54%) increases and minor (≤ 5%) to substantial (≤ 29%) decreases estimated in the Bay-Delta; increases and/or decreases at/or above 5% in averaged flows are expected between 8% to 42% of the months (Table O-202, Table O-206, and Table O-210). At SWP and CVP exports, moderate (≤ 25%) flow increases are expected an average of 2 months (generally April and May) and slight (≤ 13%) flow decreases in March and June; the remaining months (generally July through February) have minor (≤ 4%) projected increases and decreases in flow. For Delta outflow, slight (≤ 6%) decreases are generally expected in May; the remaining months (generally June through April) have minor (≤ 5%) projected increases and decreases under most phases of Alternative 2. At the confluence of Old and Middle River in the Delta, substantial (≤54%) increases are expected an average of 2 months (generally April and May) and a slight (≤ 8%) to moderate (29%) decreases an average of 3 months (generally January, March, and June); the remaining months are projected to have minor (≤ 4%) decreases and/or increases. These results suggest averaged flows may have beneficial and adverse impacts on striped bass.

Delta Outflow vs. Bay-Delta Species Abundance

- **Alternative 2 With TUCP Without VA**
    - Differences in Delta outflow between April and June, due to seasonal operations under Alternative 2 With TUCP Without VA compared with the No Action Alternative, may have effects on striped bass annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 there were then used as input to the relationship between outflow and abundance for the striped bass.
    - Predictions from the Delta outflow model for the striped bass indicated that the overall average abundance index for Alternative 2 With TUCP Without VA would essentially be similar when compared to the No Action Alternative across all water year types except for in critically dry years (-4% to -1%, +2% in critically dry years).
- **Alternative 2 Without TUCP Without VA**
    - Differences in Delta outflow between April and June due to seasonal operations under Alternative 2 Without TUCP Without VA compared with the No Action Alternative may have effects on striped bass annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 there were then used as input to the relationship between outflow and abundance for the striped bass.
    - Predictions from the Delta outflow model for the striped bass indicated that the overall average abundance index for Alternative 2 Without TUCP Without VA would essentially be similar to the No Action Alternative across all water year types except during critical water year types (-1% to -4%, +12% in critically dry years).
- **Alternative 2 Without TUCP Delta VA**
    - Predictions from the Delta outflow model for the striped bass indicated that the overall average abundance index for Alternative 2 Without TUCP Delta VA would essentially be similar to the No Action Alternative across all water year types except in critically dry years (-1%, +12% in critically dry years).
- **Alternative 2 Without TUCP Systemwide VA**
    - Differences in Delta outflow between April and June due to seasonal operations under Alternative 2 Without TUCP Systemwide VA compared with the No Action Alternative may have effects on striped bass annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 there were then used as input to the relationship between outflow and abundance for the striped bass.
    - Predictions from the Delta outflow model for the striped bass indicated that the overall average abundance index for Alternative 2 Without TUCP Systemwide VA would essentially be similar to the No Action Alternative across all water year types except in critically dry years (-1% to +4%, +15% in critically dry years).

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 flow and Delta Outflow species abundance modeling had some differences. The differences determined by CalSim 3 modeling suggests flows may have both beneficial and adverse impacts on striped bass. Predictions from the Delta Outflow species abundance model for striped bass indicated that the overall average abundance index for Alternative 2 would essentially be similar to the No Action Alternative during all water year types except in critically dry years when striped bass abundances may increase 2% (Alternative 2 With TUCP Without VA), 12% (Alternative 2 Without TUCP without VA and Alternative 2 without TUCP Delta VA), and 15% (Alternative 2 Without TUCP with Systemwide VA). Overall, these results suggest adverse and beneficial flow impacts on striped bass most water years and primarily beneficial impacts during critically dry water years.

Potential Changes to Entrainment of Striped Bass

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on striped bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for striped bass include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of striped bass under Alternative 2 With TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant was similar all water year types and CVP Jones Pumping Plant was similar or lower all water year types (Table O-136). At CVP Jones Pumping Plant predicted average monthly loss of striped bass was up to 12% lower on dry water years; largemouth bass generally had lower loss rates than striped bass (Table O-137). It should be noted that loss of striped bass at both facilities is common; however, the percentage differences may not imply significance at a population level.
- **Alternative 2 Without TUCP Without VA**
    - Predictions from the salvage density model for striped bass include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of striped bass under Alternative 2 Without TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant was generally similar or greater and CVP Jones Pumping Plant was similar or lower all water year types (Table O-136). At the SWP Banks Pumping Plant

predicted average monthly loss was up to 5% greater for below normal water year types and was similar all other water year types (Table O-137). At CVP Jones Pumping Plant predicted average monthly loss of striped bass was up to 6% and 12% lower on below normal and dry water years, respectively (Table O-137).

- **Alternative 2 Without TUCP Delta VA**
    - Predictions from the salvage density model for striped bass include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of striped bass under Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at the SWP Banks Pumping Plant were generally similar or greater and CVP Jones Pumping Plant were similar or lower all water year types (Table O-136). At the SWP Banks Pumping Plant predicted average monthly loss was up to 5% greater for below normal water years, and similar all other water year types (Table O-137). At CVP Jones Pumping Plant predicted average monthly loss of striped bass was up to 8% and 12% lower on below normal and dry water years, respectively; loss was similar all other water year types (Table O-137).
- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for striped bass include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of striped bass under Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at the SWP Banks Pumping Plant were generally similar or greater and CVP Jones Pumping Plant were similar or lower all water year types (Table O-136). At the SWP Banks Pumping Plant predicted average monthly loss was up to 5% greater for below normal water years; loss was similar all other water year types (Table O-137). At CVP Jones Pumping Plant predicted average monthly loss of striped bass was up to 11% lower on below normal and dry water years (Table O-137.

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative, salvage density modeling had some differences. The salvage density modeling predicted monthly loss under Alternative 2 at SWP Banks Pumping Plant are similar during all water year types except during below normal water years, when loss would generally have minor increases; at CVP Jones Pumping Plant loss would generally be slightly lower during most water year types, except during above normal and critical water years, which would be similar. Overall, these results suggest that loss would decrease at CVP Jones Pumping Plant from entrainment under most phases of Alternative 2 during most water years.

O.5.20 American Shad

O.5.20.1 Sacramento River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River. Migrating adults generally take 2 to 3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the February to April adult American shad migration into the Delta, CalSim 3 estimates of mean monthly flows below Keswick Dam under Alternative 2 range from about 3,400 cfs (with TUCP Without VA) for March during critically dry years to 24,000 cfs for February during wet water years (Table O-183). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 2 cannot be determined to have adverse impacts. Alternative 2 relative to the No Action Alternative is expected to have small effects these months, but flows are higher (up to 30%) for Alternative 2 (without TUCP with Delta and Systemwide VA) in April of critically dry water years (Table O-183). Therefore, Alternative 2 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 319 for Butte City.

Results for the analysis are summarized in Table O-138. Table O-138, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 62°F to 75°F optimal range, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Butte City (Table O-138). These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on American shad spawning and larval rearing in the Sacramento River.
- Results for **Alternative 2 Without TUCP Without VA** are identical to those for Alternative 2 With TUCP Without VA (Table O-138).

- Under **Alternative 2 Without TUCP Delta VA** for the 62°F to 75°F optimal range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at Butte City (Table O-138). There was one month-water year type combination (6.7%) with unfavorable results.). These results suggest that there would be negligible water temperature-related effects of Alternative 2 Without TUCP Delta VA on American shad spawning and larval rearing in the Sacramento River.
- Results for **Alternative 2 Without TUCP Systemwide VAs** are identical to those for Alternative 2 without TUCP Delta VA (Table O-138).

Overall, the four phases of Alternative 2 would have similar negligible effects on water temperature conditions for American shad spawning and larval rearing in the Sacramento River (Table O-138).

Summary

Alternative 2 relative to the No Action Alternative is largely expected to have negligible impacts on American shad spawning and larval rearing below Keswick Dam as flow for spawning is not a limiting factor for American shad due to differences in flow. Alternative 2 relative to the No Action Alternative will have negligible impacts on American shad spawning and larval rearing in the Sacramento River due to differences in water temperature. Therefore, the differences in flow and temperature for all phases of Alternative 2 compared to the No Action Alternative in the Sacramento River are expected to have negligible impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

In the Sacramento River, summer rearing habitat occurs in the main river from Colusa to the north Delta (Stevens et al. 1987). As the season progresses, juvenile shad move downstream and enter salt water primarily during September through November (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into the Delta, CalSim 3 estimates of mean monthly flows below Keswick Dam under Alternative 2 range from about 4,300 cfs during October in critically dry years to 9,000 cfs for September during wet water years (Table O-183). Because American shad are anadromous fish that migrate great lengths to reach their spawning grounds, these flow levels are likely to be adequate for juvenile rearing and emigration, therefore no adverse impacts are expected to result. Alternative 2 relative to the No Action Alternative are higher (18%) for Alternative 2 in November of below normal water years due to differences in flow (Table O-183). Therefore, Alternative 2 would likely have negligible flow impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F range optimal range for juvenile rearing and emigration during July through

November are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 320 for Butte City.

Results for the analysis are summarized in Table O-139. Table O-139, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 62°F to 75°F optimal range, there was one month-water year type combinations (4.0% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable results at Butte City (Table O-139). These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on American shad juvenile rearing and emigration in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 62°F to 75°F optimal range, there no month-water year type combinations (0%) with favorable or unfavorable results. These results suggest that there would be negligible water temperature-related effects of Alternative 2 Without TUCP Without VA on American shad juvenile rearing and emigration in the Sacramento River.
- Results for **Alternative 2 Without TUCP Delta VA** are identical to those for Alternative 2 without TUCP without VA.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 62°F to 75°F optimal range, there was one month-water year type combinations (4.0% of total combinations during the period) with favorable results and one combination with unfavorable results at Butte City (Table O-139).These results suggest that there would be negligible water temperature-related impact of Alternative 2 Without TUCP Systemwide VAs on American shad juvenile rearing and emigration in the Sacramento River.

Overall, Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP Delta VA would have similar negligible impacts on water temperature conditions for American shad juvenile rearing and emigration in the Sacramento River (Table O-139).

<u>Summary</u>

Alternative 2 relative to the No Action Alternative is largely expected to have negligible impacts on American shad juvenile rearing and emigration in the Sacramento River due to differences in flow. Flow for rearing and emigration is not a limiting factor for American shad. Alternative 2 relative to the No Action Alternative is also expected to have negligible impacts on American shad juvenile rearing and emigration in the Sacramento River due to differences in water temperature. Therefore, the differences in flow and temperature for Alternative 2 compared to the No Action Alternative are expected to have a negligible impacts on American shad spawning and larval rearing.

O.5.20.2 Lower American River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River. Migrating adults generally take 2 to3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962). Adult American shad migrate into the lower American River to spawn during the late spring, typically during April through early July (California Department of Fish and Wildlife 1986).

Potential Changes to American Shad from Seasonal Operations

<u>CalSim 3 Flows</u>

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Nimbus Dam and H street under Alternative 2 range from about 785 cfs for April in critically dry years with TUCP Without VA to 12,316 cfs for February of wet water years without TUCP systemwide VAs (Table O-230 and Table O-231Table O-233). Alternative 2 relative to the No Action Alternative is expected to have generally minimal effects in these months, but flows is moderately higher (100-111%) for Alternative 2 in April of critically dry water years without TUCP without VA due to differences in flow (Table AR_ND_A2 and Table O-231). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 2 cannot be determined to have adverse effects. Therefore, Alternative 2 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range for American shad spawning and larval rearing during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 97 for Hazel Avenue and Table 98 for Watt Avenue.

Results for the analysis are summarized in Table O-140. Table O-140, as described in Section O.4.20.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 62°F to 75°F optimal range for American shad spawning and larval rearing, there were zero month-water combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-140). There were zero and one month-water combinations (0.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

- Under **Alternative 2 Without TUCP Without VA** for the 62°F to 75°F optimal range for American shad spawning and larval rearing, there were zero month-water combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-140). There were two and zero month-water combinations (13.3% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Delta VA** for the 62°F to 75°F optimal range for American shad spawning and larval rearing, there were zero month-water combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-140). There were zero month-water combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 62°F to 75°F optimal range for American shad spawning and larval rearing, there were two and zero month-water combinations (13.3% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-140). There were zero and one month-water combinations (0.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP Delta VA would have positive and negative water temperature-related effects to American shad spawning and larval rearing in the lower American River. Effects of Alternative 2 Without TUCP Systemwide VAs would be more positive than the other phases.

<u>Summary</u>

Alternative 2 relative to the No Action Alternative is expected to have negligible impacts on American shad spawning and larval rearing below Nimbus Dam and at H Street due to differences in flow. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation from Hazel Avenue and Watt Avenue under all phases of Alternative 2 compared to the No Action Alternative will have beneficial and adverse impacts on American shad spawning and larval rearing in the lower American River. Therefore, the differences in flow and temperature for all phases of Alternative 2 compared to the No Action Alternative in the lower American River are expected to have some beneficial and adverse impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

American shad rearing and emigration in the lower American River is dependent on water temperatures. August through September, but before November, are optimal months for juvenile American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Nimbus Dam and H street under Alternative 2 range from about 574 cfs (w/o TUCP w/ Delta VA) for October in critically dry years to 4,111 cfs (w/o TUCP w/ Delta VA) for November of wet water years (Tables O-226 through O-233). Alternative 2 relative to the No Action Alternative is consistently lower (up to 23%, without TUCP without VA) for Alternative 2 below Nimbus Dam and H street in November during critically dry years due to differences in flow(Tables O-226 through O-233). Because American shad are anadromous fish that migrate great lengths to reach their spawning grounds, these flow levels are likely to be adequate for juvenile rearing and emigration, so no adverse impacts are expected to result. Therefore, Alternative 2 would likely have negligible flow impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for American shad juvenile rearing and emigration during July through November are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 99 for Hazel Avenue and Table 100 for Watt Avenue.

Results for the analysis are summarized in Table O-141. Table O-141, as described in Section O.4.20.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 63°F to 77°F optimal range for American shad spawning and larval rearing, there were two and zero month-water combinations (8.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-141). There were one and zero month-water combinations (4.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Without VA** for the 63°F to 77°F optimal range for American shad spawning and larval rearing, there was one month-water combinations (4.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-141). There were one and zero month-water combinations (4.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Delta VA** for the 63°F to 77°F optimal range for American shad spawning and larval rearing, there was one month-water combinations (4.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-141). There were two and zero month-water combinations (8.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

- Under **Alternative 2 Without TUCP Systemwide VAs** for the 63°F to 77°F optimal range for American shad spawning and larval rearing, there were two month-water combinations (8.0%) with favorable results at both Hazel Avenue and Watt Avenue, respectively (Table O-141). There were three and zero month-water combinations (12.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, the four phases of Alternative 2 would have positive and negative water temperature-related effects to American shad juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Alternative 2 relative to the No Action Alternative is largely expected to have negligible impacts on American shad juvenile rearing and emigration due to differences in flow. Flow for rearing and emigration is not a limiting factor for American shad. Water temperatures for larval rearing and emigration at Hazel Avenue and Watt Avenue under all phases of Alternative 2 compared to the No Action Alternative would have beneficial and adverse impacts on American shad juvenile rearing and emigration in the lower American River. Therefore, the differences in flow and temperature for all phases of Alternative 2 compared to the No Action Alternative are expected to have beneficial and adverse impacts on American shad juvenile rearing and emigration.

O.5.20.3 Stanislaus River

Spawning and Larval Rearing

American shad migrate up the Stanislaus River to spawn in the late spring and support a sport fishery during that period. American shad have been observed on occasion from June through July at Lovers Leap (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). American shad were found primarily in the faster habitats and were observed in schools of 20 or more (U.S. Fish and Wildlife Service 2002).

Potential Changes to American Shad from Seasonal Operations

<u>CalSim 3 Flows</u>

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Goodwin Dam and Stanislaus River mouth under Alternative 2 range from about 200 cfs for March in critically dry years to about 2200 cfs for February below Goodwin Dam and Stanislaus River Mouth in wet water years with and without TUCP and VAs (Tables O-234 though O-241). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Alternative 2 relative to the No Action Alternative is moderately higher (43%) for Alternative 2 in February of dry water years below Goodwin Dam and 10% higher at Stanislaus River Mouth with and without TUCP and VAs due to differences in flow(Tables O-234 through O-241) This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected, but Alternative 2 cannot be determined to have adverse effects. Therefore, Alternative 2 would likely have negligible impacts on American shad eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range for American shad spawning and larval rearing during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 73 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-142. Table O-142, as described in Section O.4.20.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 59°F to 68°F 62°F to 75°F optimal range for American shad spawning and larval rearing, there were one month-water year type combinations (6.7%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-142).
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-142).

Overall, the four phases of Alternative 2 would have negligible water temperature-related effects on American shad spawning and larval rearing in the Stanislaus River at Orange Blossom Bridge.

Alternative 2 relative to the No Action Alternative is largely expected to have negligible impacts on American shad spawning and larval rearing. Flow for spawning is not a limiting factor for American shad due to differences in flow. Water temperatures for spawning initiation at Orange Bridge Dam and above the confluence under Alternative 2 compared to the No Action Alternative will have negligible water-temperature related impacts on American shad spawning and larval rearing at Orange Blossom Bridge in the Stanislaus River. Therefore, the differences in flow and temperature for Alternative 2 compared to the No Action Alternative in the lower American River are expected to have negligible impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

American shad rearing and emigration in the Stanislaus River is dependent on water temperatures. From Orange Blossom Bridge to just above the confluence, juvenile rearing and emigration generally occur in July for American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Goodwin Dam and Stanislaus River Mouth under Alternative 2 range from about 200 cfs for November in critically dry years to 870 cfs in October

during wet water years below Goodwin Dam and Stanislaus River mouth with and without TUCP and VAs (Tables O-234 through O-241). Alternative 2 relative to the No Action Alternative is unchanged for Alternative 2 below Goodwin Dam with and without TUCP and VAs and 28% to 42% higher at Stanislaus River Mouth with and without TUCP and VAs in September during critically dry years due to differences in flow (Tables O-234 through O-241). With no change below Goodwin Dam and an increase in flows at Stanislaus River Mouth, there should be no adverse impacts to American shad from Alternative 2. Therefore, Alternative 2 would likely have negligible flow impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for American shad juvenile rearing and emigration during July through November are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 74 for Orange Blossom Bridge and Table 75 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-143. Table O-143, as described in Section O.4.20.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 63°F to 77°F optimal range for American shad juvenile rearing and emigration there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-143). There were zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-143).

Overall, the four phases of Alternative 2 would have negligible water temperature-related effects on American shad juvenile rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Alternative 2 relative to the No Action Alternative is largely expected to have negligible impact on American shad juvenile rearing and emigration. Flow for rearing and emigration is not a limiting factor for American shad due to differences in flow. Water temperatures for larval rearing and emigration at Orange Blossom Bridge and above the confluence under Alternative 2 compared to the No Action Alternative are suggested to have negligible water temperature-related impacts on American shad juvenile rearing and emigration in the Stanislaus River. Therefore, the differences in flow and temperature for Alternative 2 compared to the No Action Alternative are expected to have negligible impacts on American shad juvenile rearing and emigration.

O.5.20.4 San Joaquin River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas. Migrating adults generally take 2 to3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962).

Little is known about American shad populations inhabiting the San Joaquin River. American shad may spawn in the San Joaquin River system, but their abundance is unknown.

Potential Changes to American Shad from Seasonal Operations

<u>CalSim 3 Flows</u>

During the February to April adult American shad migration into the Delta, CalSim 3 estimates of mean monthly flows in the San Joaquin River at Vernalis under Alternative 2 range from about 2,000 cfs for March critically dry years to 13,000 cfs for February of wet water years with and without TUCP and VAs (Table O-243). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Alternative 2 relative to the No Action Alternative is slightly higher (~5%) for Alternative 2 Without TUCP Delta VAs and systemwide VAs in March of critically dry water years due to differences in flow (Table O-243) This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 2 cannot be determined to have adverse impacts. Therefore, Alternative 2 would likely have negligible impacts on American shad eggs and embryos relative to the No Action Alternative.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on American shad in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

<u>Summary</u>

There may be negligible impacts from seasonal operations on American shad spawning and larval rearing based on analyses of simulated flows under Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are unlikely to have an impact on American shad juvenile rearing and non-spawning adult. Changes in water temperature from seasonal operations under Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on American shad spawning and larval rearing in the San Joaquin River. Under Alternative 2, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the American shad spawning and larval rearing period.

Juvenile Rearing and Emigration

American shad rearing and emigration is dependent on water temperatures. Generally, juvenile rearing and emigration generally occur in July for American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into the Delta, CalSim 3 estimates of mean monthly flows in the San Joaquin River at Vernalis under Alternative 2 range from about 800 cfs for September in critically dry years to 2,900 cfs for November in the San Joaquin River at Vernalis with and without TUCPs and VAs of wet water years (Table O-243). Alternative 2 relative to the No Action Alternative is slightly higher (up to 12%) for Alternative 2 in September in the San Joaquin River at Vernalis with and without TUCPs and VAs during critically dry years due to differences in flow (Table O-243). With these flows, American Shad may not be affected by Alternative 2. Therefore, Alternative 2 would likely have negligible impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on American shad in the San Joaquin River. Under Alternative 2, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile rearing and emigration period (Figure O-15).

Summary

There may be negligible impacts from seasonal operations on American shad juvenile rearing and non-spawning adults based on analyses of simulated flows under Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are unlikely to have a substantial impact on American shad juvenile rearing and non-spawning adult. Under Alternative 2, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile rearing and emigration period.

O.5.20.5 Bay-Delta

American shad spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento, Feather, American, and Yuba Rivers. Some spawning also takes place in the lower San Joaquin, Mokelumne, and Stanislaus Rivers (U.S. Fish and Wildlife Service 1995). The spawning migration may begin as early as February, but most adults migrate into the Delta in March and early April (Skinner 1962). Migrating adults generally take 2 to 3 months to pass through the Sacramento–San Joaquin estuary (Painter et al. 1979).

American shad rearing and emigration in the Bay-Delta is dependent on water temperatures. August through September, but before November, are optimal months for juvenile American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

Delta Outflow vs. Bay-Delta Species Abundance

- **Alternative 2 With TUCP Without VA**
    - Differences in Delta outflow between February and June due to seasonal operations under Alternative 2 With TUCP Without VA compared with the No Action Alternative may have effects on American shad annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the American shad.
    - Predictions from the Delta Outflow model for American shad indicated that the overall average abundance index for Alternative 2 With TUCP Without VA would essentially be similar to mean abundance under the No Action Alternative across all water year types (-2% to 0%).
- **Alternative 2 Without TUCP Without VA**
    - Differences in Delta outflow between February and June due to seasonal operations under Alternative 2 Without TUCP and without VA compared with the No Action Alternative may have effects on American shad annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the American shad.
    - Predictions from the Delta Outflow model for American shad indicated that the overall average abundance index for Alternative 2 Without TUCP and without VA would essentially be similar to the mean abundance under the No Action Alternative across all water year types except during critical water year types (-2% to 0%, +7% during critical water year types).
- **Alternative 2 Without TUCP Delta VA**
    - Differences in Delta outflow between February and June due to seasonal operations under Alternative 2 Without TUCP Delta VA compared with the No Action Alternative may have effects on American shad annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the American shad.
    - Predictions from the Delta Outflow model for American shad indicated that the overall average abundance index for Alternative 2 Without TUCP Delta VA would essentially be similar to the mean abundance under the No Action Alternative across all water year types except in critically dry years (-1% to +2%, +6% during critically water year types).

- **Alternative 2 Without TUCP Systemwide VA**
    - Differences in Delta outflow between February and June due to seasonal operations under Alternative 2 Without TUCP and systemwide VA compared with the No Action Alternative may have effects on American shad annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the American shad.
    - Predictions from the Delta Outflow model for American shad indicated that the overall average abundance index for Alternative 2 Without TUCP Systemwide VA would potentially lead to slightly higher American shad abundances than the No Action Alternative in the driest years (+4% in below normal years, +5% in dry years, and +10% in critically dry years).

Summary

There may be negligible impacts from of seasonal operations on American shad spawning and larval rearing based on analyses of simulated flows under Alternative 2 in comparison to the No Action Alternative. American shad abundance index is similar to the No Action Alternative for all phases of Alternative 2 except for Alternative 2 Without TUCP with systemwide VA where there could potentially be an increase in American shad abundances during critically dry years in the Bay-Delta based from the Delta Outflow model. Therefore, Alternative 2 would not have a substantial change when compared to the No Action Alternative.

Potential Changes to Entrainment of American Shad

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on American shad entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for white surgeon include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of American shad under Alternative 2 With TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant was similar for all water year types and CVP Jones Pumping Plant were similar most water year types (Table O-144). At CVP Jones Pumping Plant predicted average monthly loss was similar water years, except dry water year types when loss decreased up to 5%. It should be noted that loss of American shad at both facilities is common; however, the percentage differences may not imply significance at a population level.

- **Alternative 2 Without TUCP Without VA**
    - Predictions from the salvage density model for American shad include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of American shad under Alternative 2 Without TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were similar most water year types (Table O-144). At the SWP Banks Pumping Plant predicted average monthly loss was similar for all water year types, except during critically dry water year types when it decreased up to 6% (Table O-145). At CVP Jones Pumping Plant predicted average monthly loss was generally similar except during dry water years when loss increased up to 5% (Table O-144).
- **Alternative 2 Without TUCP Delta VA**
    - Predictions from the salvage density model for American shad include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of American shad under Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were similar most water year types (Table O-144). At the SWP Banks Pumping Plant predicted average monthly loss was similar for all water year types, except during critically dry water year types when it decreased up to 9% (Table O-145). At CVP Jones Pumping Plant predicted average monthly loss was generally similar except during dry water years when loss increased up to 5% (Table O-144). It should be noted that loss of American shad at both facilities is common; however, the percentage differences may not imply significance at a population level.
- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for American shad include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of American shad under Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at the SWP Banks Pumping Plant was similar for all water year types and CVP Jones Pumping Plant were similar most water year types (Table O-144). At the SWP Banks Pumping Plant predicted average monthly loss was similar for all water year types, except during critically dry water year types when it decreased up to 9% (Table O-145). It should be noted that loss of American shad at both facilities is common; however, the percentage differences may not imply significance at a population level.

Summary

There may be beneficial and adverse changes to American shad entrainment based on analyses of simulated exports under all phases Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, entrainment was similar to the No Action Alternative for most what year types with some exceptions that decreased and increased during certain phases and water year types.

O.5.21 Threadfin Shad

O.5.21.1 Sacramento River

Spawning for threadfin shad takes place in California April through August, peaking in June and July. The embryos hatch in 3 to 6 days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Threadfin shad are occasionally caught at the Red Bluff Diversion Dam RST in the Sacramento River, and occur year-round (Voss 2024).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 2 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal spawning range during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 321 for Butte City.

Results for the analysis are summarized in Table O-146. Table O-146, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 63°F to 77°F optimal range, there were zero month-water year type combinations (0.0% of total combinations during the period) with favorable results and one combination (4.0%) with unfavorable results at Butte City (Table O-146). These results suggest that there would be negligible negative water temperature-related effects of Alternative 2 With TUCP Without VA on threadfin shad spawning in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA**, **VA** for the 63°F to 77°F optimal range, there were zero month-water year type combinations (0.0% of total combinations during the period) with favorable and unfavorable results at Butte City (Table O-146). These results suggest there would be negligible water temperature-related effects of Alternative 2 without TUCP without VA on threadfin shad spawning in the Sacramento River.
- Results for **Alternative 2 Without TUCP Delta VA** are identical to those of Alternative 2 With TUCP Without VA (Table O-146).
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 63°F to 77°F optimal range, there were zero month-water year type combinations (0.0% of total combinations during the period) with favorable results at Butte City (Table O-146). There were three month-water year type combinations (12.0%) with unfavorable results at Butte City. These results suggest that there would be negative effects of Alternative 2 With TUCP Without VA on threadfin shad spawning in the Sacramento River.

Overall, Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP Delta VA would have similar negligible effects on water temperature conditions for threadfin shad spawning in the Sacramento River (Table O-146). However, Alternative 2 Without TUCP Systemwide VAs would have a negative effect.

Summary

There may be negligible to adverse impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are expected to have a negligible impact on threadfin. Temperature analysis suggests adverse impacts on spawning under Alternative 2 Without TUCP with Systemwide VAs and negligible impacts under all other phases in the Sacramento River.

O.5.21.2 Lower American River

Spawning for threadfin shad takes place in California April through August, peaking in June and July. The embryos hatch in 3 to 6 days and larvae immediately become planktonic. Threadfin shad are occasionally captured as part of the non-salmonid bi-catch in the RSTs in the lower American River (Pacific States Marine Fisheries Commission 2014).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 2 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for threadfin shad adult spawning during April through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 101 for Hazel Avenue and Table 102 for Watt Avenue.

Results for the analysis are summarized in Table O-147. Table O-147, as described in Section O.4.21.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 63°F to 77°F optimal range for threadfin shad spawning, there were two and zero month-water combinations (8.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-147). There were zero and one month-water combination (0.0% and 4.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Without VA** for the 63°F to 77°F optimal range for threadfin shad spawning, there were one and zero month-water combinations (4.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-147). There was one month-water combination (4.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Delta VA** for the 63°F to 77°F optimal range for threadfin shad spawning, there were one and zero month-water combinations (4.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-147). There were zero month-water combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 63°F to 77°F optimal range for threadfin shad spawning, there were two and one month-water combinations (8.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-147). There were zero month-water combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

Overall, the four phases of Alternative 2 would have positive and negative water temperature related effects to threadfin shad spawning in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There may be negligible, beneficial and adverse impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are expected to have a negligible impact on threadfin shad. Water temperature analysis suggests beneficial and adverse impacts on spawning for the four phases of Alternative 2 in the lower American River.

O.5.21.3 Stanislaus River

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Threadfin shad are occasionally captured in the Caswell RST in the lower Stanislaus River (Bradbury and Hickey 2019).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 2 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for threadfin shad adult spawning during April through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 76 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-148. Table O-148, as described in Section O.4.21.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for 63°F to 77°F optimal range for threadfin shad adult spawning, there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge (Table O-148).
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-148).

Overall, the four phases of Alternative 2 would have negligible water temperature-related effects on threadfin shad spawning in the Stanislaus River at Orange Blossom Bridge.

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are expected to have a negligible impact on threadfin shad. Temperature analysis also suggests negligible impacts for Alternative 2 in the Stanislaus River on threadfin shad spawning.

O.5.21.4 San Joaquin River

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Juveniles can form dense schools and while they are typically abundant in freshwater, they may also be found in varying salinities throughout the estuary. Threadfin shad are fast-growing but short-lived, with an average lifespan of two years.

Potential Changes to Threadfin Shad from Seasonal Operations

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 2 are likely adequate for threadfin shad.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on threadfin shad in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows under the four phases of Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, changes in flows are expected to have a negligible impacts on threadfin shad. Under Alternative 2, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout year in the San Joaquin River at Vernalis.

O.5.21.5 Bay-Delta

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Juveniles can form dense schools and while they are typically abundant in freshwater, they may also be found in varying salinities throughout the estuary. Threadfin shad are fast-growing but short-lived, with an average lifespan of two years.

Potential Changes to Threadfin Shad from Seasonal Operations

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 2 are likely adequate for threadfin shad.

Summary

There may be negligible impacts from seasonal operations on threadfin shad under the four phases of Alternative 2 in comparison to the No Action Alternative.

Potential Changes to Entrainment of Threadfin Shad

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have impacts on threadfin shad entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation n*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for white surgeon include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at

SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.

- Predicted average monthly loss of threadfin shad under Alternative 2 With TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant was similar for all water year types and CVP Jones Pumping Plant were similar most water year types (Tables O-149 and O-150). At CVP Jones Pumping Plant predicted average monthly loss was similar water years, except dry and critically dry water year types when loss decreased up to 6%.

- **Alternative 2 Without TUCP Without VA**

  - Predictions from the salvage density model for threadfin shad include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.

  - Predicted average monthly loss of threadfin shad under Alternative 2 Without TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant was similar most water year types (Tables O-149 and O-150). At the SWP Banks Pumping Plant predicted average monthly loss was similar for all water year types, except during dry water year types when it decreased up to 6% (Table O-149). At CVP Jones Pumping Plant predicted average monthly loss was generally similar except during critically dry water years when loss increased up to 10% and dry water years when loss decreased up to 5% (Table O-150). It should be noted that loss of threadfin shad at both facilities is common; however, the percentage differences may not imply significance at a population level.

- **Alternative 2 Without TUCP Delta VA**

  - Predictions from the salvage density model for threadfin shad include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.

  - Predicted average monthly loss of threadfin shad under Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at the SWP Banks Pumping Plant was similar most water year types and CVP Jones Pumping Plant decreased or increased most water year types (Tables O-149 and O-150). At the SWP Banks Pumping Plant predicted average monthly loss was similar for all water year types, except during dry water year types when it increased up to 6% (Table O-149). At CVP Jones Pumping Plant predicted average monthly decreased up to 5% on below normal and dry water years; loss increased up to 5% on critically dry water years. Table O-150). It should be noted that loss of threadfin shad at both facilities is common; however, the percentage differences may not imply significance at a population level.

- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for threadfin shad include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of threadfin shad under Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant was similar most water year types (Tables O-149 and O-150). At the SWP Banks Pumping Plant predicted average monthly loss was similar for all water year types, except during dry water year types when it increased up to 8% (Table O-149). At CVP Jones Pumping Plant predicted average monthly loss was generally similar except during critically dry water years when loss increased up to 5% and below normal water years when loss decreased up to 5% (Table O-150). It should be noted that loss of threadfin shad at both facilities is common; however, the percentage differences may not imply significance at a population level.

Summary

There may be beneficial and adverse changes to entrainment on threadfin shad juvenile rearing and non-spawning adults based on analyses of simulated exports under Alternative 2 in comparison to the No Action Alternative. Under Alternative 2, entrainment increased at SWP Banks Pumping Plant across all phases water year types except during the dry and critically dry water year types for the phases without VAs and decreased at CVP Jones Pumping Plant for all water year types and phases except during the critical water year type for the phases without TUCP.

O.5.22 Black Basses

O.5.22.1 Three Micropterus spp.

Three *Micropterus* spp. constitute the group of black basses in California, and include largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species). All three species are introduced but have recreational value in California.

Largemouth Bass

Largemouth bass first spawn during their second or third spring at about 7 inches in length. Spawning is limited to freshwater (Moyle 2002). The males begin building nests when the water temperature reaches about 60°F (15.6°C). Spawning takes place from April through June, at temperatures up to 75°F (23.9°C).

Smallmouth Bass

Smallmouth bass reach maturity in their third or fourth spring, at which point they move into shallower water. Spawning begins in May and can continue into June or July (Moyle 2002). Spawning has been observed at temperatures ranging from 13°C to 26°C (55.4°F to 78.8°F), with optimal water temperatures ranging from 16°C to 18°C (60.8°F to 64.4°F) (Wang 2010).

Spotted Bass

Maturity is reached in the second or third year and spawning occurs in freshwater when temperatures reach 15°C to 18°C (59°F to 64.4°F), continuing until temperatures reach 22°C to 23°C (71.6°F to 73.4°F) in early June. Males move to shallow water in March and early April, where they construct nests 40 to 80 cm (31.5 inches) in diameter, generally in shallow areas less than or equal to 6 m deep (University of California, Agriculture and Natural Resources 2019b; Wang 2010).

O.5.22.2 Sacramento River

Spawning

Spawning occurs in freshwater for all three taxa. This means all spawning occurs upstream of the brackish estuary. See details in Section O.4.22.1 above for spawning timing for each species.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative mean monthly flows at Keswick Dam, Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤6%) increases and decreases are estimated most months April through July; March would remain the same as the No Action Alternative. Minor increases would generally occur in April. Minor decreases would typically occur in June and July. This suggests largemouth, smallmouth, and spotted habitat will largely remain similar to the No Action Alternative under Alternative 2 (Table O-186 through Table O-189, Table O-190 through Table O-193, and Table O-194 through Table O-197).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 323 for Butte City. Full results of the analysis assessing the percent of months with water temperature outside the 55°F to 70°F optimal range for smallmouth bass spawning during May through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 325 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 331 for Butte City.

Results for the three analyses are summarized in Table O-151. Table O-151, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-151). For the 55°F to 70°F optimal range for smallmouth bass spawning, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Hamilton City. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Butte City. These results suggest that there would be negligible water temperature-related effects of Alternative 2 With TUCP Without VA on black bass spawning in the Sacramento River.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** were identical to those of Alternative 2 With TUCP Without VA (Table O-151).

Overall, all four phases of Alternative 2 would have similar negligible effects on water temperature conditions for black bass spawning in the Sacramento River (Table O-151).

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative for CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will remain largely similar, except April, June, and July when minor beneficial and adverse (respectively) impacts on largemouth, smallmouth, and spotted bass may be expected. The optimal water temperature range modeling estimates indicate neither beneficial nor adverse impacts on largemouth, smallmouth, and spotted bass under Alternative 2 compared to the No Action Alternative. Overall, these results suggest there would be generally minor adverse flow impacts on largemouth, smallmouth, and spotted bass spawning habitat in June and negligible water temperature-related impacts compared to the No Action Alternative for all three species in the Sacramento River under Alternative 2.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters. However, they require large quantities of food; they are likely to remain in slower moving waters of the stream or move vertically within the lake to accommodate preferences.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative mean monthly flows at Keswick Dam, Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤5%) increase and/or decrease is estimated most months except April (Keswick Dam) and June (Red Bluff Diversion Dam) under Alternative 2 With TUCP with Systemwide VA when a 6% increase and a 5% decrease, respectively, occur. This suggests largemouth, smallmouth, and spotted habitat will largely remain similar to the No Action Alternative under Alternative 2 (Table O-186 through Table O-189, Table O-190 through Table O-193, and Table O-194 through Table O-197).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 324 at Butte City. Full results of the analysis assessing the percent of months with water temperature above the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 327 for the Sacramento River at Hamilton. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for non-spawning adult smallmouth bass growth year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 320 for the Sacramento River at Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 332 for the Sacramento River at Butte City.

Results for the four analyses are summarized in Table O-152. Table O-152, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-152). For the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass, there were no month-water year type combinations (0%) with favorable results and two combinations (13.3%) with unfavorable results at Hamilton City. For the 77°F to 80°F optimal range for non-spawning adult smallmouth bass growth, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Hamilton City. For the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Butte City. These results suggest that there would be negative water temperature-related effects of Alternative 2 With TUCP Without VA on black bass non-spawning adults in the Sacramento River.
- Under **Alternative 2 Without TUCP Without VA** for the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-152). For the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass, there were no month-water year type combinations (0%) with favorable results and three combinations (20.0%) with unfavorable results at Hamilton City. For the 77°F to 80°F optimal range for non-spawning adult smallmouth bass growth, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Hamilton City. For the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass, there were no month-water year type combinations (0%) with either favorable or unfavorable

results at Butte City. These results suggest that there would be negative water temperature-related effects of Alternative 2 Without TUCP Without VA on black bass non-spawning adults in the Sacramento River.

- Results for **Alternative 2 Without TUCP Delta VA** and **Alternative 2 Without TUCP Systemwide VAs** were identical to those for Alternative 2 With TUCP Without VA (Table O-152).

Overall, all four phases of Alternative 2 would have similar negative effects on water temperature conditions for black bass spawning in the Sacramento River (Table O-152).

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative for CalSim 3 flow and water temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will largely remain similar, except April (Keswick Dam) and June (Red Bluff Diversion Dam) under Alternative 2 With TUCP with Systemwide VA which had slight beneficial and adverse (respectively) impacts on largemouth, smallmouth, and spotted bass. The optimal summer water temperature range modeling estimates indicate were neither beneficial nor adverse conditions for largemouth and spotted bass compared to the No Action Alternative at Butte and Hamilton cities. The optimal summer water temperature range modeling estimates indicate two to three month-water year type combinations) with adverse results for smallmouth bass at lower end of optimal range at Hamilton City. Overall, these Alternative 2 results suggest that there would be minor adverse impacts from flow for largemouth, smallmouth, and spotted bass. There would be no water temperature-related impacts on largemouth and spotted bass, but there would be adverse temperature-related effects on smallmouth bass in the Sacramento River.

O.5.22.3 Lower American River

Spawning

Spawning for all three taxa occurs in cooler, shallow waters with flow. See details in Section O.4.22.1 above for spawning timing for each species.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam, and at H Street indicate that minor (≤ 5%) increase and decrease is estimated for March through July, except April under Alternative 2 With TUCP with Systemwide VA when a slight increase would occur (6% below Nimbus Dam, 7% at H street) (Table O-222 through Table O-225, Table O-226 through Table O-229, and Table O-230 through Table O-233). These results suggest flows will remain largely similar, except April a minor increase in flow. Flow effects on largemouth, smallmouth, and spotted bass would be generally similar to the No Action Alternative under Alternative 2, except in April when minor beneficial impacts may occur.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 105 for Hazel Avenue and Table 106 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 55°F to 70°F optimal range for smallmouth bass spawning during May through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 109 for Hazel Avenue and Table 110 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 115 for Hazel Avenue and Table 116 for Watt Avenue.

Results for the three analyses are summarized in Table O-153. Table O-153, as described in Section O.4.22.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-153). There were also zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 55°F to 70°F optimal range for smallmouth bass spawning, there were 0 month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero and one month-water year type combinations (0.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were also zero and two month-water year type combinations (0.0% and 13.2%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Without VA** for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-153). There were zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 55°F to 70°F optimal range for smallmouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero and one month-water year type combinations (0.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero month-water year type combinations (0.0%) with unfavorable results at Hazel Avenue and Watt Avenue.

- Under **Alternative 2 Without TUCP Delta VA** for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-153). There were zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 55°F to 70°F optimal range for smallmouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there was one month-water year type combination (6.7%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero and two month-water year type combinations (0.0% and 13.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-153). There were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 55°F to 70°F optimal range for smallmouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were three and zero month-water year type combinations (20.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and two month-water year type combinations (0.0% and 13.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, the four phases of Alternative 2 would have similar positive and negative effects on water temperature conditions for spawning black basses in the lower American River.

<u>Summary</u>

Overall, under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 flow modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will remain largely similar to the No Action Alternative, except April when minor beneficial impacts on largemouth, smallmouth, and spotted bass may occur. Temperature modeling suggests that the four phases of Alternative 2 would have both beneficial and adverse effects.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters. However, they require large quantities of food; they are likely to remain in slower moving waters of the stream or move vertically within the lake to accommodate preferences.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam and at H Street indicate that minor (≤ 5%) increase and/or decrease is estimated for most months except April under Alternative 2 With TUCP with Systemwide VA when a slight increase occurs (6% below Nimbus dam and 7% at H street) (Table O-226 through Table O-229 and Table O-230 through Table O-233). These results suggest flows will remain largely similar, except April which would have a slight increase in flow. Flow effects on largemouth, smallmouth, and spotted bass would be generally similar to the No Action Alternative under Alternative 2.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for growth for largemouth bass during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 107 for Hazel Avenue and Table 108 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 111 for Hazel Avenue and Table 112 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for growth in smallmouth bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 113 for Hazel Avenue and 114 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 75°F to 87°F preferred summer-time range for spotted bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 117 for Hazel Avenue and Table 118 for Watt Avenue.

Results for the four analyses are summarized in Table O-154. Table O-154, as described in Section O.4.22.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue (Table O-154). There were also zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were 0 month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-

water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero and one month-water year type combinations (0.0% and 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue.

- Under **Alternative 2 Without TUCP Without VA** for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue (Table O-154). There were also zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were 0 month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were also 0 month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Delta VA** for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-154). There were also zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there were three and zero month-water year type combinations (20.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and zero month-water year type combinations (6.7% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were 0 month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.
- Under **Alternative 2 Without TUCP Systemwide VAs** for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-154). There were also zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 66°F water temperature lower end

of observed summer-time range of non-spawning adult smallmouth bass, there were two and zero month-water year type combinations (13.3% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were three and zero month-water year type combinations (20.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero and one month-water year type combinations (0.0% and 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

Overall, the four phases of Alternative 2 would have positive and negative effects on water temperature conditions for non-spawning adult black bass species in the lower American River.

Summary

Overall, there were differences between all phases of Alternative 2 and the No Action Alternative in CalSim 3 flow and temperature modeling. The differences determined by CalSim 3 modeling suggests spawning habitat extent will remain largely similar, except one to two months out of the year with slight beneficial and/or adverse impacts on largemouth, smallmouth, and spotted bass. The water temperature analysis indicates beneficial and adverse impacts on non-spawning largemouth, smallmouth, and spotted bass in the lower American River.

O.5.22.4 Stanislaus River

Spawning

Spawning for all three taxa occurs in cooler, shallow waters with flow. See details in Section O.4.22.1 above for spawning timing for each species. The Stanislaus River supports spawning for largemouth bass and spotted bass.

Potential Changes to Largemouth and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 simulated averaged water year type flows fluctuates between minor (≤ 1%) to slight (≤ 13%) increases and minor (≤ 1%) to slight (≤ 8%) decreases are estimated at Goodwin Dam and mouth of the Stanislaus River (Table O-234 through Table O-237 and Table O-238 through Table O-241). At Goodwin Dam, slight (≤ 12%) increases are expected in July and a slight (8%) decrease in April. At the mouth of the Stanislaus River, flow is expected to remain similar (<5%) to the No Action Alternative April through July. These results suggest flows may be anticipated to have generally negligible impacts on largemouth, smallmouth, and spotted bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 78 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 82 for Orange Blossom Bridge.

Results for the two analyses are summarized in Table O-155. Table O-155, as described in Section O.4.22.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there was one month-water year type combinations (6.7%) with favorable and 0 month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-155). For the 58.1°F to 73.4°F observed range for spotted bass spawning, there was two month-water year type combinations (13.3%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-155).

Overall, the four phases of Alternative 2 would have positive effects on water temperature conditions for spawning black basses in the Stanislaus River.

Summary

CalSim 3 modeling suggests that projected flows in the Stanislaus River under Alternative 2 are expected to have negligible impacts on spawning for largemouth, smallmouth, and spotted bass. Analysis of projected water temperature changes suggests that Alternative 2 would likely have positive impacts on spawning behavior for these species in the Stanislaus River.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters. However, they require large quantities of food; they are likely to remain in slower moving waters of the stream or move vertically within the reservoirs to accommodate preferences.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 simulated averaged water year type flows fluctuates between minor (≤ 1%) to slight (≤ 13%) increases and minor (≤ 1%) to slight (≤ 8%) decreases are estimated at Goodwin Dam and mouth of the Stanislaus River (Table O-234 through Table O-237 and Table O-238 through Table O-241). At Goodwin Dam,

slight (≤ 13%) increases are expected an average of 4 months (December, February, July, and August) and a slight (8%) decrease in April; other increases and decreases in flow are minor (≤ 5%). At the mouth, on average slight (≤ 10%) increases are expected in August and September; the remaining increases and decreases in flow are minor (≤ 4%). These results suggest flows may be anticipated to have generally beneficial on largemouth, smallmouth, and spotted bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for growth for largemouth bass during year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 79 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass during June through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 80 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for growth in smallmouth bass during year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 81 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 75°F to 87°F preferred summer-time range for spotted bass during June through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 83 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-156. Table O-156, as described in Section O.4.22.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

- Under **Alternative 2 With TUCP Without VA** for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Road (Table O-156). For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Road. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Road For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Road.
- Results for **Alternative 2 Without TUCP Without VA**, **Alternative 2 Without TUCP Delta VA**, and **Alternative 2 Without TUCP Systemwide VAs** are identical to those of Alternative 2 With TUCP Without VA (Table O-156).

Overall, the four phases of Alternative 2 would have a negligible effect on water temperature conditions for non-spawning adult black bass species in the Stanislaus River at Orange Blossom Road.

Summary

CalSim 3 modeling suggests flows may have generally beneficial impacts on largemouth, smallmouth, and spotted bass. The optimal water temperature range modeling estimates were neither beneficial nor adverse for largemouth, smallmouth, and spotted bass. Overall, these results suggest generally beneficial flow impacts and negligible water temperature-related impacts on non-spawning largemouth, smallmouth, and spotted bass in the Stanislaus River under Alternative 2 compared to the No Action Alternative.

O.5.22.5 San Joaquin River

Spawning occurs in freshwater for all three taxa. This means all spawning occurs upstream of the brackish estuary. Non-spawning adults are generally more tolerant of various water quality parameters and may be found from the tributaries of the San Joaquin to the brackish estuary. As all three taxa require large quantities of food, they are more likely to be concentrated in areas with plentiful food and instream cover.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows vary between minor (≤ 3%) increases and/or decreases are estimated at Vernalis most months; however, minor (6%) to substantial (≤ 34%) increases are generally expected June through September of critically dry water years (Table O-242 through Table O-245). These results suggest flows will largely be similar to the No Action Alternative under all phases of Alternative 2, except in June through September of dry water years beneficial effects on largemouth, smallmouth, and spotted bass are expected.

Changes in water temperature from seasonal operations under the four phases of Alternative 2 compared to the No Action Alternative are likely to have a negligible impact on black basses in the San Joaquin River. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 flow modeling suggest flows will be largely similar; beneficial impacts on largemouth, smallmouth, and spotted bass may be expected June through September of dry water years. Under the four phases of Alternative 2, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.5.22.6 Bay-Delta

Non- spawning adults are present year-round predominantly in the brackish water interface where food is abundant. Larvae and Juveniles are likely to remain upstream of the brackish water interface, where plant beds and slower waters occur.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

All phases of Alternative 2 compared to the No Action Alternative CalSim 3 mean monthly flows vary between minor (≤5%) to substantial (≤ 52%) increases and minor (≤ 5%) to substantial (≤ 29%) decreases are estimated in the Bay-Delta (Table O-202, Table O-206, and Table O-210). For SWP and CVP exports, moderate (≤ 25%) flow increases are expected generally in April and May, and slight (≤ 13%) decreases in March and June. For Delta outflow, slight (≤ 6%) decreases are generally expected in May; all other differences in flow are minor (≤ 5%). At the confluence of Old and Middle River in the Delta, substantial (≤54%) increases are generally expected in April and May, and a slight (≤ 6%) to moderate (≤ 29%) decreases are generally expected January, March, and June; all other flow differences minor (≤ 4%). These results suggest averaged flows may be anticipated to have beneficial and adverse impacts on largemouth, smallmouth, and spotted bass.

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative CalSim 3 flow and salvage density modeling had some differences. The differences determined by CalSim 3 modeling suggests flows may have both beneficial and adverse impacts on largemouth, smallmouth, and spotted bass.

Potential Changes to Entrainment of Largemouth Bass

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on largemouth bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for largemouth bass include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of largemouth bass under Alternative 2 With TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant was generally similar and CVP Jones Pumping Plant was lower all water year types, except wet water years (Tables O-157 and O-158). At the SWP Banks Pumping Plant predicted average monthly loss was up to 20% greater for below normal water years; on critically dry water years, largemouth bass loss was up to 5% lower (Table O-157). At CVP Jones Pumping Plant predicted average monthly loss of largemouth bass was up to 12% lower on dry water years (Table O-158).

- **Alternative 2 Without TUCP Without VA**
    - Predictions from the salvage density model for largemouth bass include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of largemouth bass under Alternative 2 Without TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant were generally similar or greater and CVP Jones Pumping Plant were similar or lower all water year types (Tables O-157 and O-158). At the SWP Banks Pumping Plant predicted average monthly loss was up to 21% greater for below normal water year types (Table O-157). At CVP Jones Pumping Plant predicted average monthly loss of largemouth bass was up to 10% and 11% lower on below normal and dry water years; loss was similar to No Action Alternative all other water year types (Table O-158).
- **Alternative 2 Without TUCP Delta VA**
    - Predictions from the salvage density model for largemouth bass include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of largemouth bass under Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at the SWP Banks Pumping Plant was generally similar or greater and CVP Jones Pumping Plant was similar or lower all water year types (Tables O-157 and O-158). At the SWP Banks Pumping Plant predicted average monthly loss was up to 20% and 109%greater for below normal and critically dry water years, respectively (Table O-157). At CVP Jones Pumping Plant predicted average monthly loss of largemouth bass was up to 12% lower on dry water years (Table O-158).
- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for largemouth bass include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of largemouth bass under Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at the SWP Banks Pumping Plant was generally similar or greater and CVP Jones Pumping Plant was similar or lower all water year types (Tables O-157 and O-158). At the SWP Banks Pumping Plant predicted average monthly loss was up to 20% and 113% greater on below normal and critically dry water years (Table O-157). At CVP Jones Pumping Plant predicted average monthly loss of largemouth bass was up to 11% lower on dry water years (Table O-158).

Potential Changes to Entrainment of Smallmouth Bass

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on smallmouth bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for smallmouth bass include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of smallmouth bass of Alternative 2 With TUCP Without VA compared to the No Action at SWP Banks Pumping Plant was similar all water year types, except in dry water years when loss would decrease and critically dry water year types when no fish are expected; at CVP Jones Pumping Plant loss would be similar on below normal and critically dry water year types, all other water year types have no anticipated loss (Tables O-159 and Table O-160). At the SWP Banks Pumping Plant predicted average monthly loss decreased up to 5% in October of dry water years and was similar to the No Action Alternative all other water years loss is expected (Table O-159). Historic loss of smallmouth bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.
- **Alternative 2 Without TUCP Without VA**
    - Predictions from the salvage density model for smallmouth bass include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.
    - Predicted average monthly loss of smallmouth bass of Alternative 2 Without TUCP Without VA compared to the No Action Alternative at SWP Banks Pumping Plant was similar all water year types, except in below normal and dry water years when loss would decrease and critically dry water year types when no fish are expected; at CVP Jones Pumping Plant loss would be similar on below normal and critically dry water year types, all other water year types have no anticipated loss (Table O-159 and Table O-160). At the SWP Banks Pumping Plant predicted average monthly loss decreased up to 5% in October of below normal water years and October and March of dry water years (Table O-159). Historic loss of smallmouth bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.
- **Alternative 2 Without TUCP Delta VA**
    - Predictions from the salvage density model for smallmouth bass include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at

SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.

- Predicted average monthly loss of smallmouth bass of Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at SWP Banks Pumping Plant was similar all water year types, except in below normal water years when loss would decrease and critically dry water year types when no fish are expected; at CVP Jones Pumping Plant loss would decrease on below normal water years and be similar critically dry water years, all other water year types have no anticipated loss (Table O-159 and Table O-160). At the SWP Banks Pumping Plant predicted average monthly loss increased up to 5% in October of dry water years (Table O-159). At the CVP Jones Pumping Plant predicted average monthly loss decreased up to 10% January through March and May of below normal water years (Table O-160). Historic loss of smallmouth bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for smallmouth bass include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of smallmouth bass of Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at SWP Banks Pumping Plant was similar all water year types, except critically dry water year types when no fish are expected; at CVP Jones Pumping Plant loss would decrease on below normal and critically dry water year types, all other water year types have no anticipated loss (Table O-159 and Table O-160). At the CVP Jones Pumping Plant predicted average monthly loss decreased up to 12% January through March and May of below normal water years (Table O-160). Historic loss of smallmouth bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Potential Changes to Entrainment of Spotted Bass

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on spotted bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**
    - Predictions from the salvage density model for spotted bass include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.

- Predicted average monthly loss of spotted bass of Alternative 2 With TUCP Without VA compared to the No Action Alternative at SWP Banks Pumping Plant was similar in below normal water years and no fish are expected all other water year types; at CVP Jones Pumping Plant loss was similar most water year types, except critically dry water years when loss would decrease (Table O-161 and Table O-162). At the CVP Jones Pumping Plant predicted average monthly loss decreased up to 10% in January and August of critically dry water years (Table O-162). Historical loss of spotted bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

- **Alternative 2 Without TUCP Without VA**

  - Predictions from the salvage density model for spotted bass include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.

  - Predicted average monthly loss of spotted bass of Alternative 2 Without TUCP Without VA compared to the No Action Alternative at SWP Banks Pumping Plant decreased below normal water years and no fish are expected all other water year types; at CVP Jones Pumping Plant loss was similar most water year types, except critically dry water years when loss would decrease (Table O-161 and Table O-162). At the SWP Banks Pumping Plant predicted average monthly loss decreased up to 6% in March of below normal water years (Table O-161). At the CVP Jones Pumping Plant predicted average monthly loss decreased up to 7% in January and August of critically dry water years (Table O-162). Historical loss of spotted bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

- **Alternative 2 Without TUCP Delta VA**

  - Predictions from the salvage density model for spotted bass include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.

  - Predicted average monthly loss of spotted bass of Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at SWP Banks Pumping Plant decreased below normal water years and no fish are expected all other water year types; at CVP Jones Pumping Plant loss was similar most water year types, except below normal and critically dry water years when loss would decrease (Table O-161 and Table O-162). At the SWP Banks Pumping Plant predicted average monthly loss decreased up to 29% greater in March of below normal water years (Table O-161). At the CVP Jones Pumping Plant predicted average monthly loss decreased up to 12% in March, April, and December of below normal water years and 11% in January and August of dry water years (Table O-162).

- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for spotted bass include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of spotted bass of Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at SWP Banks Pumping Plant decreased below normal water years and no fish are expected all other water year types; at CVP Jones Pumping Plant loss was similar most water year types, except below normal and critically dry water years when loss would decrease (Table O-161 and Table O-162). At the SWP Banks Pumping Plant predicted average monthly loss decreased up to 27% greater in March of below normal water years (Table O-161). At the CVP Jones Pumping Plant predicted average monthly loss decreased up to 13% in March, April, and December of below normal water years and 12% in January and August of dry water years (Table O-162).

Summary

Overall, under all phases of Alternative 2 compared to the No Action Alternative salvage density modeling had some differences. The salvage density modeling predicted monthly largemouth bass loss to due entrainment under Alternative 2 compared to the No Action Alternative are similar or lower (CVP Jones Pumping Plant) most water year types and generally greater (SWP Banks Pumping Plant) in below normal and critically dry water years. The salvage density modeling predicted monthly loss of smallmouth bass under Alternative 2 compared to the No Action Alternative are similar or slightly to largely lower for smallmouth and spotted bass for nearly all water year types. Overall, these results suggest largemouth bass loss decreases at CVP Jones Pumping Plant most water year types and increases at SWP Banks Pumping Plant during below normal and critically dry water year types due to entrainment; results suggest generally beneficial flow impacts on smallmouth and spotted bass loss decreases from entrainment under Alternative 2.

O.5.23 Starry Flounder

O.5.23.1 Bay-Delta

Adult starry flounder primarily inhabit coastal marine waters (Orcutt 1950; Haertel and Osterberg 1967; Bottom et al. 1984; Hieb and Baxter 1993). Distribution of age-0 juveniles within the San Francisco Estuary and Delta is primarily in Suisun Bay and San Pablo Bay, with lower abundance in the west Delta (Baxter et al. 1999). Starry flounder older than age 1 (age-1+ fish) occur principally in San Pablo Bay, Suisun Bay, and Central Bay (Baxter et al. 1999).

Starry flounder can tolerate a wide range of salinities. In the Sacramento and San Joaquin Rivers, starry flounder have been observed in salinities as low as 0.02–0.06 ppt (i.e., essentially fresh water) (Orcutt 1950). Age-0 and age-1+ starry flounder are a common species in estuarine habitats along the West Coast (see Orcutt 1950; Pearson 1989; Emmett et al. 1991; Baxter et al. 1999; Kimmerer 2002b).

Spawning occurs primarily during the winter months of December and January (Orcutt 1950). By age-2 many starry flounder are nearing reproductive maturity and have migrated to ocean habitats adjacent to their natal estuaries. Adults may move seasonally into shallow coastal waters to spawn, perhaps in proximity to estuaries to take advantage of estuarine circulation which would advect fertilized eggs near the bottom into nursery areas.

Potential Changes to Starry Flounder from Seasonal Operations

Delta Outflow vs. Bay-Delta Species Abundance

- **Alternative 2 With TUCP Without VA**
    - Differences in Delta outflow between March and June due to seasonal operations under Alternative 2 With TUCP Without VA compared with the No Action Alternative may have effects on starry flounder annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the starry flounder.
    - Predictions from the Delta Outflow model for starry flounder indicated that the overall average abundance index for Alternative 2 With TUCP Without VA would essentially be similar to mean abundance under the No Action Alternative across all water year types (ranging from -2% to -3%, +3% in critically dry years).
- **Alternative 2 Without TUCP Without VA**
    - Differences in Delta outflow between March and June due to seasonal operations under Alternative 2 Without TUCP and without VA compared with the No Action Alternative may have effects on starry flounder annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the starry flounder.
    - Predictions from the Delta Outflow model for starry flounder indicated that the overall average abundance index for Alternative 2 Without TUCP and without VA would essentially be similar to mean abundance under the No Action Alternative across all water year types except critically dry water year types (-4% to 0%, +17% during critically dry water year types).
- **Alternative 2 Without TUCP Delta VA**
    - Differences in Delta outflow between March and June due to seasonal operations under Alternative 2 Without TUCP Delta VA compared with the No Action Alternative may have effects on starry flounder annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the starry flounder.

- Predictions from the Delta Outflow model for starry flounder indicated that the overall average abundance index for Alternative 2 Without TUCP Delta VA would essentially be similar to mean abundance under the No Action Alternative across all water year types except in critically dry years (ranging from -1% to +4%, +17% in critically dry years).

- **Alternative 2 Without TUCP Systemwide VA**

  - Differences in Delta outflow between March and June due to seasonal operations under Alternative 2 Without TUCP and systemwide VA compared with the No Action Alternative may have effects on starry flounder annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the starry flounder.

  - Predictions from the Delta Outflow model for starry flounder indicated that the overall average abundance index for Alternative 2 Without TUCP Systemwide VA would potentially lead to slightly higher starry flounder abundances than the No Action Alternative in the driest years (+8% in below normal Years, +9% in dry years, and +24% in critically dry years).

Summary

Alternative 2 relative to the No Action Alternative and their impacts on starry flounder abundance in the Delta generally differ between each phase but would best be explained in three groups due to differences in flow. The first group would be Alternative 2 With TUCP and without VA, and Alternative 2 Without TUCP and Delta VA. Under each of these phases, impacts would generally be negligible, with overall starry flounder abundance predicted to be similar to the No Action Alternative across all water year types with the exception being critically dry years, when abundance would slightly increase. Alternative 2 Without TUCP Without VA would likely have no impacts on starry flounder, as abundance was found to be essentially similar to the No Action Alternative across all water year types. Finally, Alternative 2 Without TUCP Systemwide VA would possibly be the most beneficial phase, potentially leading to higher starry flounder abundances than the No Action Alternative in all types of dry years.

Potential Changes to Entrainment of Starry Flounder

Differences in exports under the four phases of Alternative 2 compared with the No Action Alternative may have effects on starry flounder entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

- **Alternative 2 With TUCP Without VA**

  - Predictions from the salvage density model for starry flounder include mean monthly total exports. Table O-202 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 With TUCP Without VAs and the No Action Alternative.

- Predicted average monthly loss of starry flounder under Alternative 2 With TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant increased most water year types, except critically dry water years when loss was similar; at CVP Jones Pumping Plant loss was similar most water year types, except critically dry water years when loss decreased (Table O-163 and Table O-164). At the SWP Banks Pumping Plant predicted average monthly loss increase ranged from 15% in December through July of wet water years and February through August of below normal water years to 49% in March, April, May, July, August, and November of dry water years (Table O-163). At CVP Jones Pumping Plant predicted average monthly loss was generally similar except during January and September of critically dry water year types when loss decreased up to 8% (Table O-164). Historical loss of starry flounder at both facilities is infrequent, and this is a driver of low values of predicted loss.

- **Alternative 2 Without TUCP Without VA**

  - Predictions from the salvage density model for starry flounder include mean monthly total exports. Table O-203 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP Without VAs and the No Action Alternative.

  - Predicted average monthly loss of starry flounder under Alternative 2 Without TUCP Without VA compared to the No Action Alternative at the SWP Banks Pumping Plant increased or decreased all water year types and CVP Jones Pumping Plant was similar all water year types (Table O-163 and Table O-164). At the SWP Banks Pumping Plant predicted average monthly loss increase ranged from 15% in December through July of wet water years to 49% in March, April, May, July, August, and November of dry water years; loss decreased in October of critically dry water years up to 10% (Table O-163). Historical loss of starry flounder at both facilities is infrequent, and this is a driver of low values of predicted loss.

- **Alternative 2 Without TUCP Delta VA**

  - Predictions from the salvage density model for starry flounder include mean monthly total exports. Table O-204 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.

  - Predicted average monthly loss of starry flounder under Alternative 2 Without TUCP Delta VA compared to the No Action Alternative at the SWP Banks Pumping Plant increased most water year types, except critically dry water years when loss decreased; at CVP Jones Pumping Plant loss decreased most water year types, except above normal and critically dry water years when loss was similar (Table O-163 and Table O-164). At the SWP Banks Pumping Plant predicted average monthly loss increase ranged from 7% in December through July of above normal water years to 49% in March, April, May, July, August, and November of dry water years; loss decreased in October of critically dry water years up to 10% (Table O-163). At CVP Jones Pumping Plant predicted average

monthly loss decrease ranged from 5% in June through October of wet water years and May and November of below normal water years to 11% in March through August of dry water years (Table O-163). Historical loss of starry flounder at both facilities is infrequent, and this is a driver of low values of predicted loss.

- **Alternative 2 Without TUCP Systemwide VA**
    - Predictions from the salvage density model for starry flounder include mean monthly total exports. Table O-205 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 2 Without TUCP with Delta VAs and the No Action Alternative.
    - Predicted average monthly loss of starry flounder under Alternative 2 Without TUCP Systemwide VA compared to the No Action Alternative at the SWP Banks Pumping Plant increased most water year types, except critically dry water years when loss was similar; at CVP Jones Pumping Plant loss decreased in most water year types, except above normal and critically dry water years when loss was similar (Table O-163 and Table O-164). At the SWP Banks Pumping Plant predicted average monthly loss increase ranged from 6% in December through July of above normal water years to 22% in March, April, May, July, August, and November of dry water years (Table O-163). At CVP Jones Pumping Plant predicted average monthly loss decrease ranged from 5% in June through October of wet water years and May and November of below normal water years to 12% in March through August of dry water years (Table O-163). Historical loss of starry flounder at both facilities is infrequent, and this is a driver of low values of predicted loss.

Summary

For salvage density at SWP Banks Pumping Plant, there would be an adverse impact on starry flounder in most water year types, except for critically dry years when loss would be negligible or minorly beneficial. Salvage loss at CVP Jones Pumping Plant was a negligible impact for Alternative 2 With TUCP Without VA and without TUCP Without VA. For Alternative 2 Without TUCP Delta VA and without TUCP Systemwide VA, there would be a beneficial impact on salvage, except during above normal and critically dry years when loss would be negligible.

O.5.24 Coastal Pelagic Species

O.5.24.1 Potential Changes to Northern Anchovy and Pacific Herring from Seasonal Operations

Northern anchovy and Pacific herring could be subject to operational effects of the Proposed Action as it pertains to Delta outflow and its effect on the salinity field. However, the effects on salinity would be small relative to the salinity tolerance of Coastal Pelagic Species EFH such as Northern Anchovy (Baxter et al. 1999). Kimmerer et al. (2009) showed for Northern Anchovy that neither indices of habitat extent nor indices of abundance were related to X2, an index of Delta outflow and its effects.

Kimmerer (2009) found Pacific herring abundance indices were not associated with flow. However, Pacific herring do utilize the San Francisco Bay Estuary as spawning and rearing habitat (Pak et al. 2023, Grimaldo et al. 2020, Watters et al. 2004). Grimaldo et al. (2020) found Pacific herring larvae presence and abundance was lower in landward regions (e.g. Suisun Bay) during a high outflow year, likely due to either increased advection from high flows or reduced net landward movement via gravitational circulation. Juvenile herring abundance in Suisun Bay in the spring is associated with saltier conditions that allow their range to expand landward (Pak et al. 2023).

O.5.24.2 Potential Changes to Entrainment of Northern Anchovy and Pacific Herring

There are no expected impacts to entrainment of Northern anchovy due to operations since the distribution in the San Francisco Estuary has shifted towards higher salinities (> 20) since the introduction of the invasive clam, Potamocorbula amurensis (Kimmerer 2006). Impacts to entrainment of Pacific herring are potentially adverse in drier water year types depending on severity but are likely to be extremely rare. Historical salvage of Pacific herring has only occurred a few times since 2000, primarily in 2014, a critically dry year (during the months of March and April), fish were also salvaged in 2019 and 2020 in much lower numbers (CDFW 2024c).

O.5.25 Upper Klamath-Trinity River Spring-run Chinook Salmon ESU

O.5.25.1 Trinity River

Spawning and Egg/Alevin Incubation

Most spring-run Chinook salmon in the Trinity River spawn from late September to mid-November, with a peak in October (Gough et al. 2021a,b). At optimal intragravel temperatures (41–55°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another 4–6 weeks (Healey 1991, Moyle 2002). In the Trinity River, spring-run Chinook salmon incubation and emergence typically occurs through February (Leidy and Leidy 1984). The effects of flow and water temperature on spring-run Chinook salmon spawning and egg/alevin incubation may therefore occur from approximately mid-September through February.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

<u>Alternative 2 With TUCP Without VA</u>

Under Alternative 2 With TUCP Without VA, modeled monthly average flows in the Trinity River below Lewiston Dam would be at least 5% lower than the No Action Alternative only in November of above normal water years, in December of below normal water years, and in February of wet water years (Table O-174). Modeled monthly average flows under Alternative 2 With TUCP Without VA would increase by at least 5% in February and March of above normal water years compared with the No Action Alternative. The November flow decrease would occur during the primary spring-run Chinook salmon spawning period and the December and February flow decreases, as well as the February flow increase, would occur during the egg/alevin incubation period. The monthly flow differences would have minor effects on the availability or suitability of spawning and egg/alevin incubation habitat for spring-run Chinook salmon relative to the No Action Alternative. Under Alternative 2 With TUCP Without VA, like the No Action

Alternative, the variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

Modeled monthly average flow in November of above normal water years would decrease from 403 cfs under the No Action Alternative to 363 cfs under Alternative 2 With TUCP Without VA (Table O-174), which may benefit spawning spring-run Chinook salmon by increasing WUA for spawning adults in the primary spawning reach from Lewiston Dam to North Fork Trinity River compared with the No Action Alternative (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999, Rupert et al. 2017a, b). Comparative effects on spawning suitability would vary in downstream reaches, with a decrease in spawning WUA from North Fork Trinity River to South Fork Trinity River and an increase in spawning WUA from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In all reaches of the Trinity River, the effects of flow changes on spawning and incubation suitability are likely to vary spatially with channel confinement and incision (Goodman et al. 2018). Where the channel is naturally unconfined and not overly incised and where channel restoration has removed remnant riparian berms and reduced legacy channel confinement and incision, a stronger positive relationship between flow and salmonid habitat suitability, particularly for flows of approximately 300–1,200 cfs, can be expected than in areas of greater channel confinement (see Section O.4.24.1.1 for a detailed discussion). This is mainly a result of increasing habitat area, which provides more space for redds and reduces the risk of redd superimposition by later-spawning salmonids.

In December of below normal water years modeled monthly average flow in the Trinity River below Lewiston Dam would decrease from 931 cfs under the No Action Alternative to 880 cfs under Alternative 2 With TUCP Without VA (Table O-174). In February of wet water years, modeled monthly average flows would decrease from 1,843 cfs under the No Action Alternative to 1,706 cfs under Alternative 2 With TUCP Without VA. The December and February flow decreases would occur during the spring-run Chinook salmon egg/alevin incubation period. Although WUA for egg/alevin incubation is not available for the Trinity River, the lower monthly average flows in December and February under Alternative 2 With TUCP Without VA would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative, especially in areas with a confined channel where relatively minor changes in flow have little influence on water depth or velocity, and no impacts on egg/alevin incubation suitability are expected.

Modeled monthly average flow in the Trinity River below Lewiston Dam would increase in February of above normal water years from 1,194 cfs under the No Action Alternative to 1,390 cfs under Alternative 2 With TUCP Without VA and in March of above normal water years from 1,021 cfs under the No Action Alternative to 1,095 cfs under Alternative 2 With TUCP Without VA (Table O-174). The February flow increase would occur during the spring-run Chinook salmon egg/alevin incubation period but is not expected to change redd hydraulics or other conditions that may affect incubation suitability. No effects on egg/alevin incubation suitability are expected.

Modeled monthly average water temperature in the Trinity River below Lewiston Dam in November of above normal water years and December of below normal water years would not differ from the No Action Alternative (Figure O-18 and Figure O-19, respectively), while in February of wet water years the modeled monthly average water temperature may increase slightly under Alternative 2 With TUCP Without VA compared with the No Action Alternative (Figure O-17). In February of above normal water years, modeled monthly average water temperature in the Trinity River below Lewiston Dam may decrease slightly compared with the No Action Alternative. November water temperatures under Alternative 2 With TUCP Without VA would remain well below the upper water temperature objective of 56°F (Table O-11) to protect spawning spring-run Chinook salmon in the reach from Lewiston Dam to the North Fork Trinity River (Asarian et al. 2023). In December and February, water temperatures from Lewiston Dam to North Fork Trinity River would remain below the 50°F (10°C) upper optimum limit recommended by USEPA (2001, as cited in Carter 2005) in all water year types to support spring-run Chinook salmon incubation and emergence (Asarian et al. 2023). Water temperatures under Alternative 2 With TUCP Without VA would have negligible impacts on spring-run Chinook salmon spawning and incubation suitability compared with the No Action Alternative.

Compared with the No Action Alternative, the impacts of seasonal operations under Alternative 2 With TUCP Without VA would likely have minor impacts on the availability and suitability of spring-run Chinook salmon spawning and incubation habitat in the Trinity River. Overall, the impacts in the reaches most heavily used by spawning spring-run Chinook salmon would likely be negligible or slightly beneficial, with spatial variability related to the impacts of channel geometry on habitat suitability.

Alternative 2 Without TUCP Without VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be very similar to flows under Alternative 2 With TUCP Without VA, except for a smaller increase (greater than 5%) in February of above normal water years (Table O-175) and a slightly smaller decrease (greater than 5%) in February of wet water years. During the spring-run Chinook salmon spawning and incubation period, modeled monthly average flows in November of above normal water years, December of below normal water years, and February of wet water years would be at least 5% less than flows under the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on spring-run Chinook salmon spawning and incubation as those described for Alternative 2 With TUCP Without VA. Compared with the No Action Alternative, the increased average flow in February of above normal water years would is not expected to affect egg/alevin incubation suitability. Overall, the impacts of seasonal operations under Alternative 2 Without TUCP Without VA on the availability and suitability of spring-run Chinook salmon spawning and incubation habitat would likely be negligible or slightly beneficial compared with the No Action Alternative, with spatial variability related to the impacts of channel geometry on habitat suitability.

Alternative 2 Without TUCP With Delta VA

Compared with the No Action Alternative, substantial (greater than 5%) reductions in monthly average flow under Alternative 2 Without TUCP With Delta VA would occur in November of above normal water years and February of wet water years. Effects on spring-run Chinook

salmon spawning and egg/alevin incubation at these times would be nearly identical to those under Alternative 2 With TUCP Without VA. Increased flow (greater than 5%) in February of above normal water years would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative is not expected to affect egg/alevin incubation suitability.

Like Alternative 2 With TUCP Without VA, the November flow decrease would not result in changes in average water temperature in the Trinity River below Lewiston Dam (Figure O-18 and Figure O-19). Average water temperature in the Trinity River below Lewiston Dam in February of wet water years may increase slightly under Alternative 2 Without TUCP With Delta VA compared with the No Action Alternative (Figure O-17) but water temperatures from Lewiston Dam to North Fork Trinity River would remain below the 50°F (10°C) upper optimum limit recommended by USEPA (2001, as cited in Carter 2005) in all water year types to support spring-run Chinook salmon incubation and emergence (Asarian et al. 2023). The potential impacts on the availability and suitability of spring-run Chinook salmon spawning and egg/alevin incubation habitat that may result from the small November and February differences in monthly average flow and water temperature relative to the No Action Alternative would be the same as those described for Alternative 2 With TUCP Without VA.

Overall, the impacts in the reaches most heavily used by spawning spring-run Chinook salmon would likely be negligible or slightly beneficial, with spatial variability related to the impacts of channel geometry on habitat suitability.

Alternative 2 Without TUCP With Systemwide VA

Monthly average flows under Alternative 2 Without TUCP With Systemwide VA in November of above normal water years and February of wet water years would be at least 5% less than flows under the No Action Alternative and nearly identical to Alternative 2 Without TUPC With Delta VA as well as associated differences in water temperature and would have the same impacts on spring-run Chinook salmon spawning and incubation as those described for Alternative 2 Without TUCP With Delta VA.

In February of above normal water years, monthly average flow would increase by 132 cfs from 1,194 cfs under the No Action Alternative to 1,326 cfs under Alternative 2 Without TUCP With Systemwide VA (Table O-177). This increase would not be expected to have measurable impacts on depth, velocity, or substrate that could affect suitability for incubating spring-run Chinook salmon eggs/alevins. Similarly, the February flow increase would not result in measurable changes in average water temperature in the Trinity River below Lewiston Dam (Figure O-18) and there would be no change in the water temperature suitability for incubating spring-run Chinook salmon eggs/alevins relative to the No Action Alternative.

Juvenile Rearing and Emigration

In the Trinity River, spring-run Chinook salmon fry emerge from the gravel beginning in December and most emergence is complete by the end of February (Leidy and Leidy 1984). Fry and juvenile Chinook salmon rearing in the Trinity River preferentially use areas of relatively slow water velocity and habitat with woody material, undercut banks, and other complex cover (Hampton 1988, Pinnix et al. 2019). Naturally spawned juvenile spring-run Chinook salmon typically outmigrate as sub-yearlings from the Trinity River and occasionally as yearlings.

Hatchery releases of spring-run Chinook salmon also include mostly sub-yearlings and some yearling releases in spring and fall, respectively. Peak outmigration of natural and hatchery origin juveniles occurs in May, June, and July based on monitoring in the lower Trinity River near the town of Willow Creek (Harris et al. 2016; Petros et al. 2017). The effects of flow and water temperature on rearing and emigrating spring-run Chinook salmon may therefore occur from December through July.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, modeled monthly average flows in the Trinity River below Lewiston Dam would be more than 5% lower than the No Action Alternative in November of above normal water years, in December of below normal water years, and in February of wet water years (Table O-174). In February and March of above normal water years, modeled monthly average flows under Alternative 2 With TUCP Without VA would increase by at least 5% compared with the No Action Alternative.

The December, February, and March differences may have spatially variable effects on the availability and suitability of juvenile rearing and emigration habitat for spring-run Chinook salmon. The decrease in modeled monthly average flow in December of below normal water years from 931 cfs under the No Action Alternative to 880 cfs under Alternative 2 With TUCP Without VA would result in a decrease in fry WUA and an increase in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, an increase in both fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and a decrease in fry WUA and an increase in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The monthly average flow reductions in February of wet water years from 1,843 cfs to 1,706 cfs would result in reductions in WUA for fry and juvenile spring-run Chinook salmon from Lewiston Dam to Dutch Creek, small increases in fry and juvenile WUA from Dutch Creek to North Fork Trinity River, a slight decrease in fry WUA and a small increase in juvenile WUA from North Fork Trinity River to South Fork Trinity River, and little to no change in fry and juvenile WUA from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

The modeled monthly flow increase in February of above normal water years from 1,194 cfs under the No Action Alternative to 1,390 cfs under Alternative 2 With TUCP Without VA would result in an increase in Chinook salmon fry WUA and decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek and a decrease in both fry and juvenile WUA in the reaches from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In March of above normal water years, the increase in modeled monthly average flow from 1,021 cfs under the No Action Alternative to 1,095 cfs under Alternative 2 With TUCP Without VA would result in an increase in Chinook salmon fry WUA and decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, a decrease in both fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and an increase in fry WUA and very small decrease in juvenile WUA from South Fork Trinity River to Weitchpec.

Where the channel is naturally unconfined and not overly incised and in locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships and rearing WUA in some restored areas may exhibit a stronger positive relationship to flow up to approximately 3,500 cfs (Cooper-Hertel et al. 2022). Consequently, spring-run Chinook salmon WUA in all reaches is likely to vary spatially with channel confinement and incision and WUA in restored areas may be greater than described in U.S. Fish and Wildlife Service and Hoopa Valley Tribe (1999). See Section O.4.24.1.1 for additional details. The potential changes in WUA for spring-run Chinook salmon fry and juveniles may have minor, short-term effects on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the eight-month rearing period and in some reaches of the Trinity River.

In December of below normal water years, differences in modeled monthly average flows between Alternative 2 With TUCP Without VA and the No Action Alternative would not result in changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-19). In February of wet water years, reductions in modeled monthly average flows between Alternative 2 With TUCP Without VA and the No Action Alternative may slightly increase modeled monthly average water temperatures below Lewiston Dam compared with the No Action Alternative (Figure O-17). In December and February of the aforementioned water year types, modeled monthly average water temperatures at Trinity River below Lewiston Dam under Alternative 2 With TUCP Without VA would remain well below the 62.6°F water temperature objective for emigrating juvenile spring-run Chinook salmon recommended for normal and wetter water year types and the 68°F objective recommended for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that water temperatures in December and February would remain below both objectives under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating spring-run Chinook salmon under Alternative 2 With TUCP Without VA relative to the No Action Alternative.

Compared with the No Action Alternative, seasonal operations under Alternative 2 With TUCP Without VA would likely have negligible impacts on the availability and suitability of spring-run Chinook salmon juvenile rearing and emigration habitat in the Trinity River. The impacts would vary spatially due to the impacts of channel geometry on habitat suitability.

<u>Alternative 2 Without TUCP Without VA</u>

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be very similar to flows under Alternative 2 With TUCP Without VA, except for a smaller increase (greater than 5%) in February of above normal water years and a slightly larger decrease (greater than 5%) in February of wet water years (Table O-175). Monthly average flows in November of above normal water years, December of below normal water years, and February of wet water years would be at least 5% less than flows under the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same effects on spring-run Chinook salmon juvenile rearing and emigration as those described for Alternative 2 With TUCP Without VA.

In February of above normal water years, modeled monthly average flow would increase by 145 cfs from 1,194 cfs under the No Action Alternative to 1,339 cfs under Alternative 2 Without TUCP Without VA (Table O-175). This increase may result in a small increase in spring-run Chinook salmon fry WUA and a decrease in juvenile WUA in the Trinity River from Lewiston Dam to Dutch Creek and small decreases in fry and juvenile WUA in downstream reaches (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The flow increase in February of above normal water years would not result in changes in modeled average water temperature in the Trinity River below Lewiston Dam (Figure O-18) and, as described for Alternative 2 With TUCP Without VA, there would be no change in the temperature suitability for rearing and emigrating spring-run Chinook salmon relative to the No Action Alternative.

Alternative 2 Without TUCP With Delta VA

Compared with the No Action Alternative, substantial (greater than 5%) reductions in modeled monthly average flow in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Delta VA would occur in November of above normal water years and February of wet water years (Table O-176). Modeled monthly average flow in February of above normal water years would increase substantially (greater than 5%) under Alternative 2 Without TUCP With Delta VA relative to the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same effects on spring-run Chinook salmon juvenile rearing and emigration as those described for Alternative 2 With TUCP Without VA for November and February.

Alternative 2 Without TUCP With Systemwide VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be similar to flows under Alternative 2 Without TUCP With Delta VA, but with a larger increase in February of above normal water years (Table O-177). Modeled monthly average flows in November of above normal water years and February of wet water years would be at least 5% less than flows under the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on spring-run Chinook salmon juvenile rearing and emigration as those described for Alternative 2 Without TUCP With Delta VA.

In February of above normal water years, modeled monthly average flow would increase by 132 cfs from 1,194 cfs under the No Action Alternative to 1,326 cfs under Alternative 2 Without TUCP With Systemwide VA (Table O-177). This increase may result in a small increase in spring-run Chinook salmon fry WUA and a decrease in juvenile WUA in the Trinity River from Lewiston Dam to Dutch Creek and small decreases in fry and juvenile WUA in downstream reaches (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The flow increase in February of above normal water years would not result in changes in average water temperature in the Trinity River below Lewiston Dam (Figure O-18) and, as described for Alternative 2 With TUCP Without VA, there would be no change in the temperature suitability for rearing and emigrating spring-run Chinook salmon relative to the No Action Alternative.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon typically enter the Trinity River from April through September. By the end of July, most fish have arrived at the primary spawning reach, which extends from Lewiston Dam downstream to the confluence with the North Fork Trinity River. After entering freshwater, spring-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically begins in late September (Leidy and Leidy 1984; Gough et al. 2019, 2021a,b). The effects of flow and water temperature on migrating and holding spring-run Chinook salmon adults may therefore occur from April through September.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, seasonal operations in the Trinity River are expected to provide similar habitat conditions for spring-run Chinook salmon upstream migration and holding to the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish. During the April–September spring-run Chinook salmon upstream migration and holding period there would be minor (less than 5%) differences in modeled monthly average flow between the two alternatives in April and no differences in May through September (Table O-174). The minor differences in April are not expected to result in changes in habitat suitability for migrating and holding spring-run Chinook salmon. During the entirety of the adult upstream migration and holding period, monthly average flows would be approximately 500 cfs or greater in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and holding habitat to support pre-spawning spring-run Chinook salmon.

Modeled monthly average flows in July, August and September, when adult spring-run Chinook salmon may be holding and water temperatures are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 2 With TUCP Without VA as under the No Action Alternative (Table O-174). Under both alternatives, July–September flows would maintain suitable water temperatures for adult upstream migration (60°F from July 1 to September 14 and 56°F from September 15 to September 30 at Douglas City [RM 93.7]; Table O-11) (Asarian et al. 2023). Although downstream warming during the warmest months and driest water year types could result in unsuitable water temperatures for migrating spring-run Chinook salmon at some locations (Buxton 2023), the likelihood of this occurring would be the same under Alternative 2 With TUCP Without VA as under the No Action Alternative because flows would be the same under both alternatives. Under Alternative 2 With TUCP Without VA, suitability for adult spring-run Chinook salmon upstream migration and holding would be the same as under the No Action Alternative.

Alternative 2 Without TUCP Without VA

During the April–September spring-run Chinook salmon upstream migration and holding period, modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to flows under Alternative 2 With TUCP Without VA, with minor (less than 5%) differences in modeled monthly average flow between the two alternatives in April and no differences in May through September (Table O-175). The

monthly average flows and associated monthly average water temperatures would have the same impacts on migrating and holding spring-run Chinook salmon as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Delta VA

During the April–September spring-run Chinook salmon upstream migration and holding period, modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Delta VA would be very similar to flows under Alternative 2 With TUCP Without VA, with minor (less than 5%) differences in modeled monthly average flow between the two alternatives in April and no differences in May through September (Table O-176). The monthly average flows and associated monthly average water temperatures would have the same impacts on migrating and holding spring-run Chinook salmon as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Systemwide VA

During the April–September spring-run Chinook salmon upstream migration and holding period, modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be nearly identical to flows under Alternative 2 With TUCP Without VA, with minor (less than 5%) differences in modeled monthly average flow between the two alternatives in April and no differences in May through September (Table O-177). The monthly average flows and associated monthly average water temperatures would have the same impacts on migrating and holding spring-run Chinook salmon as those described for Alternative 2 With TUCP Without VA.

O.5.26 Southern Oregon/Northern California Coast Coho Salmon ESU

O.5.26.1 Trinity River

Spawning and Egg/Alevin Incubation

Most coho salmon spawning in the mainstem Trinity River occurs in November and December between Lewiston Dam and the North Fork Trinity River (Section O.1.2.5.1, *Coho salmon, Southern Oregon/Northern California Coast ESU*). Coho salmon eggs and alevins in the Trinity and Klamath River Basins may be present in the gravel from November to mid-May (Leidy and Leidy 1984), so effects of flow and water temperature on coho salmon eggs and alevins may occur during this period.

Potential Changes to Coho Salmon from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, modeled monthly average flows in the Trinity River below Lewiston Dam would be at least 5% lower than the No Action Alternative only in November of above normal water years, in December of below normal water years, and in February of wet water years (Table O-174). Like all other phases of Alternative 2, monthly average flows averaged across the full simulation period would be slightly less in November through April than monthly average flows under the No Action Alternative. The November and December flow decreases would occur during the primary coho salmon spawning period.

Reduced modeled monthly average flow in November of above normal water years from 403 cfs under the No Action Alternative to 363 cfs under Alternative 2 With TUCP Without VA may provide minor benefits to spawning coho salmon by slightly increasing WUA for spawning adults in most portions of the Trinity River between Lewiston Dam and Weitchpec, including the most heavily used spawning reach immediately downstream of Lewiston Dam (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999; Rupert et al. 2017a, 2017b). Reduced monthly average flow in December of below normal water years from 931 cfs to 880 cfs may increase spawning WUA for coho salmon in lesser-used downstream portions of the Trinity River but is predicted to slightly reduce spawning WUA in a more heavily used upstream reach compared to the No Action Alternative (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The effect of flow differences on spawning suitability is likely to vary spatially with channel confinement and incision (Goodman et al. 2018). In locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships. The November and December flow decreases would not result in measurable changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (see Appendix F, Figure F.2.11-1-1), and average water temperatures under Alternative 2 With TUCP Without VA would remain well below the upper water temperature objective of 56°F to protect spawning coho salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11; Asarian et al. 2023).

In February of wet water years, modeled monthly average flows in the Trinity River below Lewiston Dam would be reduced from 1,843 cfs under the No Action Alternative to 1,706 cfs under Alternative 2 With TUCP Without VA. These decreases would occur during the coho salmon egg/alevin incubation period. The February flow reduction under Alternative 2 With TUCP Without VA could slightly increase the risk of dewatering of redds constructed in January compared with the No Action Alternative. This is because modeled monthly average flows under Alternative 2 With TUCP Without VA would decrease by 157 cfs from January (1,863 cfs) to February (1,706 cfs), in contrast to the No Action Alternative under which flows would decrease by only 29 cfs from January (1,872 cfs) to February (1,843 cfs) (Table O-174).

Modeled monthly average water temperature in the Trinity River below Lewiston Dam in February of wet water years may increase slightly under Alternative 2 With TUCP Without VA compared with the No Action Alternative (Figure O-17) but would remain below the 50°F upper suitability limit recommended by Washington State Department of Ecology (WDOE) (2002, as cited in Carter 2005) to support coho salmon incubation and emergence.

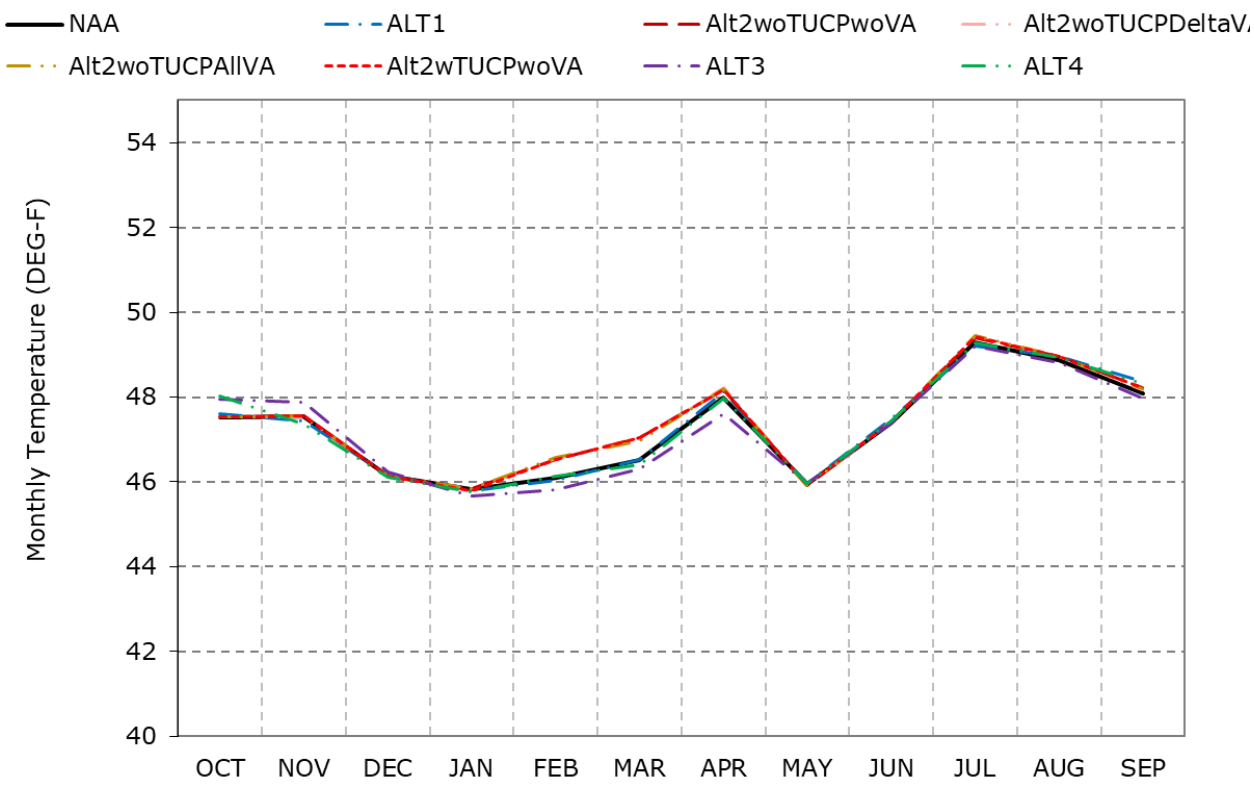


Figure O-17. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam in Wet Water Years

Alternative 2 Without TUCP Without VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to flows under Alternative 2 With TUCP Without VA (Table O-175) so impacts to coho spawning, egg incubation, and fry emergence habitat from flow changes and water temperature would be the same as Alternative 2 With TUCP Without VA.

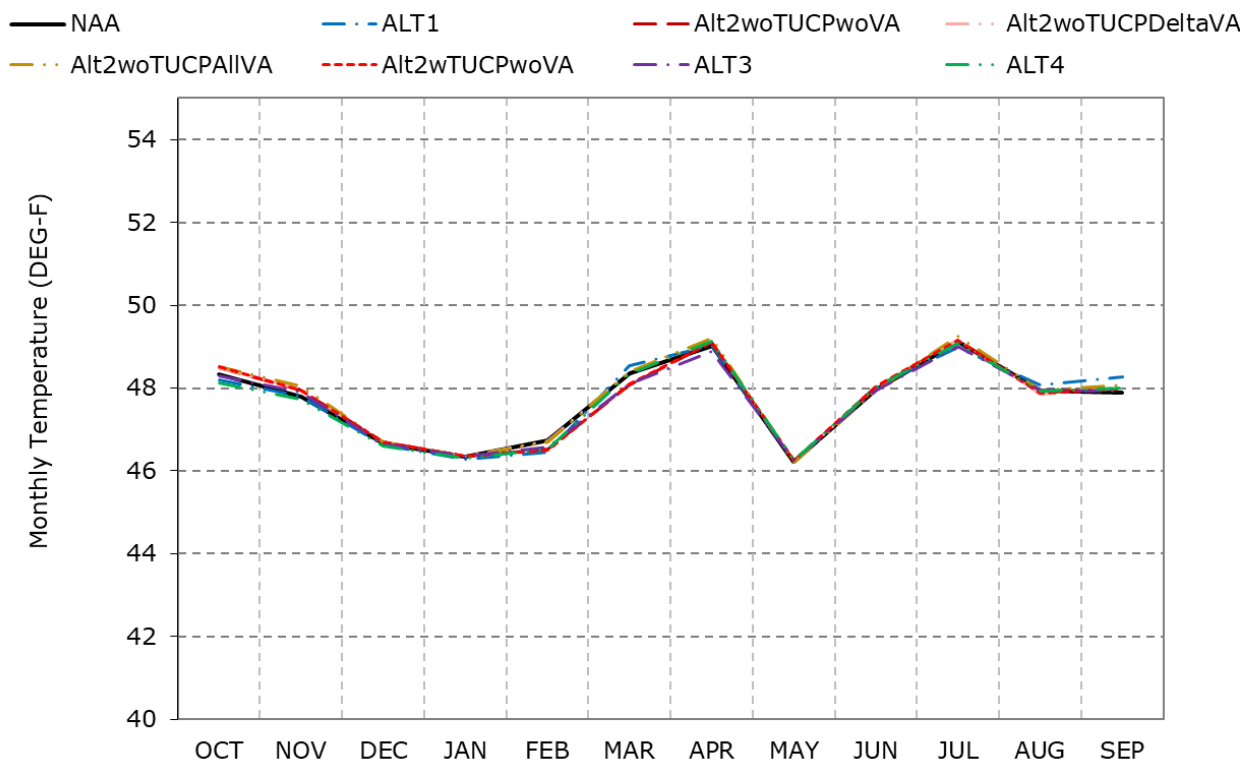


Figure O-18. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam in Above Normal Water Years

<u>Alternative 2 Without TUCP With Delta VA</u>

With regard to spawning, egg incubation, and fry emergence modeled monthly average flows in the Trinity River under Alternative 2 Without TUCP With Delta VA would be nearly identical to flows under Alternative 2 With TUCP Without VA in November and February (Table O-176). Compared with the No Action Alternative, greater than 5% reductions in modeled monthly average flow under Alternative 2 Without TUCP With Delta VA would occur in November of above normal water years and in February of wet water years. Flow increases are predicted to occur in February of above normal water years.

Like Alternative 2 With TUCP Without VA, the November flow decreases under Alternative 2 Without TUCP With Delta VA would not result in changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-18 and Figure O-19). Modeled monthly average water temperature in the Trinity River below Lewiston Dam in February of wet water years may increase slightly under Alternative 2 Without TUCP With Delta VA compared with the No Action Alternative (Figure O-17). The potential impacts on the availability and suitability of coho salmon spawning and egg/alevin incubation habitat that may result from the small differences in monthly average flow and water temperature relative to the No Action Alternative would be the same as those described for Alternative 2 With TUCP Without VA.

A graph of modeled water temperatures in the Trinity River in wet water years.

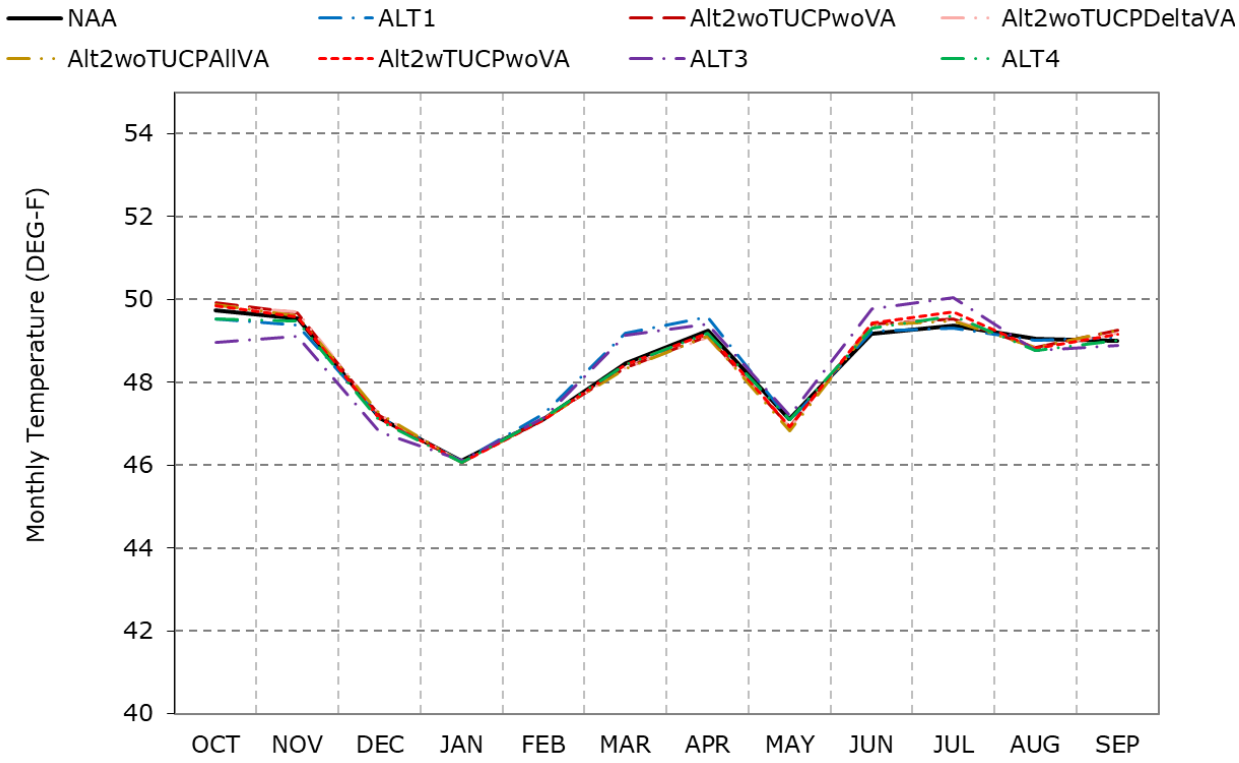


Figure O-19. Modeled Monthly Average Water Temperature in the Trinity River below Lewiston Dam in Below Normal Water Years

Alternative 2 Without TUCP With Systemwide VA

Monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be nearly identical to Alternative 2 Without TUCP With Delta VA and impacts from flow and temperature changes would be the same for coho spawning, egg incubation, and fry emergence habitat as Alternative 2 Without TUCP With Delta VA (Table O-177).

Juvenile Rearing and Emigration

Naturally spawned juvenile coho salmon in the Trinity River emerge from the gravel and begin rearing in winter and early spring, with the first captures of young-of-year (age-0) coho salmon typically occurring in early March (U.S. Fish and Wildlife Service 2023, unpublished; Yurok Tribe 2023, unpublished). Fry, juvenile, and subyearling coho salmon rearing in the Trinity River strongly prefer areas of slow water velocity and habitat with cover from woody material, overhanging vegetation, and clusters of aquatic vegetation (Hampton 1988, 1997; Chase et al. 2009; Pinnix et al. 2019). During high flows, young coho salmon use floodplains and other off-channel habitats (Chase et al. 2009). Rearing occurs year-round, typically over a period of 12–15 months, and the effects of flow and water temperature on rearing coho salmon, therefore, occur throughout the year. Most Trinity River coho salmon outmigrate to the ocean as yearling smolts between January and July (Harris et al. 2016; Petros et al. 2015; Petros et al. 2017).

Potential Changes to Coho Salmon from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, modeled monthly average flows in the Trinity River below Lewiston Dam would be more than 5% lower than the No Action Alternative in November of above normal water years, in December of below normal water years, and in February of wet water years (Table O-174). These differences may have spatially variable impacts on the availability and suitability of juvenile rearing and emigration habitat for coho salmon. The decrease in modeled monthly average flow in November of above normal water years from 403 cfs under the No Action Alternative to 363 cfs under Alternative 2 With TUCP Without VA (Table O-174) would result in minor increases in observed and predicted WUA for juvenile coho salmon in all reaches of the Trinity River from Lewiston Dam to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Similarly, the decrease in monthly average flow in December of below normal water years from 931 cfs under the No Action Alternative to 880 cfs under Alternative 2 With TUCP Without VA would result in minor increases in observed and predicted WUA for juvenile coho salmon from Lewiston Dam to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The reduced monthly average flows in February (from 1,843 cfs to 1,706 cfs) of wet water years would result in reductions in WUA for fry and juvenile coho salmon from Lewiston Dam to Dutch Creek, no change in fry and juvenile WUA from Dutch Creek to North Fork Trinity River, a slight decrease in fry WUA and a slight increase in juvenile WUA from North Fork Trinity River to South Fork Trinity River, and little to no change in fry and juvenile WUA from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The increased monthly average flows in February and March of above normal water years would result in little to no change in WUA for fry and minor reductions in WUA for juvenile coho salmon from Lewiston Dam to Weitchpec. The effect of flow differences on rearing suitability is likely to vary spatially with channel confinement and incision (Cooper-Hertel et al. 2022). In locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships. These changes in WUA for coho salmon fry and juveniles may have minor, short-term impacts on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the 12–15 month rearing period and in some reaches of the Trinity River.

In November of above normal water years and in December of below normal water years, differences in modeled monthly average flows between Alternative 2 With TUCP Without VA and the No Action Alternative would not result in changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-18 and Figure O-19, respectively). In February of wet water years, differences in monthly average flows between Alternative 2 With TUCP Without VA and the No Action Alternative may slightly increase modeled monthly average water temperatures in the Trinity River below Lewiston Dam compared with the No Action Alternative (Figure O-17). In February of above normal water years, modeled monthly average water temperature in the Trinity River below Lewiston Dam may decrease slightly compared with the No Action Alternative. In November, December, and February, of the aforementioned water year types, modeled monthly average water temperatures at Trinity River below Lewiston Dam under Alternative 2 With TUCP Without VA would remain well below the 59°F water temperature objective for emigrating juvenile coho salmon recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa

Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in November, December, and February would remain below the 59°F objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating coho salmon under Alternative 2 With TUCP Without VA relative to the No Action Alternative. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 2 With TUCP Without VA through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the coho salmon juvenile rearing and emigration period at downstream locations in some water year types under Alternative 2 With TUCP Without VA, water temperatures and the potential impacts on coho salmon would not differ from the No Action Alternative.

Alternative 2 Without TUCP Without VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to flows under Alternative 2 With TUCP Without VA (Table O-175) so impacts to juvenile rearing and emigration from flow changes and water temperature would be the same as Alternative 2 With TUCP Without VA...

Alternative 2 Without TUCP With Delta VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Delta VA would be nearly identical to flows under Alternative 2 With TUCP Without VA except for the changes in December of below normal water years and March of above normal water years. The modeled monthly average flows would be more than 5% lower than the No Action Alternative in November of above normal water years and in February of wet water years (Table O-176). These differences in monthly average flow and associated differences in modeled monthly average water temperature would have the same impacts on coho salmon juvenile rearing and emigration as those described for Alternative 2 With TUCP Without VA for November and February. However, Alternative 2 Without TUCP with Delta VA would not have the decrease in flows in December of below normal water years and associated increase in juvenile rearing habitat predicted under Alternative 2 With TUCP Without VA or the increase in flows in March of above normal water years and associated decrease in WUA.

Alternative 2 Without TUCP With Systemwide VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be nearly identical to flows under Alternative 2 Without TUCP With Delta VA and impacts to juvenile rearing and emigration would be the same as Alternative 2 Without TUCP With Delta VA (Table O-177). Adult Upstream Migration and Holding from August to January, coho salmon return from the ocean through the Klamath River Estuary to the Trinity River, moving upstream toward spawning habitat. Based on recent weir counts, the date of peak abundance of upstream-migrating coho salmon in the Trinity River ranges from late September to mid-November (Kier et al. 2018, 2019, 2020, 2021, 2022). After completing their upstream migration, mature coho salmon may hold for days, weeks, or sometimes months before spawning. Because most spawning occurs in November and

December, the impacts of flow and water temperature on migrating and holding coho salmon would primarily occur from August through December.

Potential Changes to Coho Salmon from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, seasonal operations in the Trinity River are expected to provide similar habitat conditions for coho salmon upstream migration and holding to the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish including coho salmon. During the primary coho salmon upstream migration and holding period there would be no differences in modeled monthly average flow between the two alternatives in August, September, or October and minor differences in November and December. Modeled monthly average flows in the Trinity River below Lewiston Dam would be more than 5% lower than the No Action Alternative only in November of above normal water years and in December of below normal water years (Table O-174). These differences may result in minor, short-term changes in habitat conditions but modeled monthly average flows from August through January when adult coho salmon are migrating and holding would be equal to or greater than 300 cfs in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and holding habitat to support pre-spawning coho salmon.

Modeled monthly average flows in August and September, when adult coho salmon begin migrating upstream from the ocean and water temperatures are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 2 With TUCP Without VA as under the No Action Alternative (Table O-174). Under both alternatives, modeled average August and September flows of 760 cfs in wet water years and 863 cfs in all other water year types would maintain suitable water temperatures for adult upstream migration (not to exceed 60°F in August and early September and 56°F in late September at Douglas City; Table O-11) in the Trinity River (Figure O-17). Although downstream warming during August and September could result in unsuitable water temperatures for migrating coho salmon at some locations (Asarian et al. 2023), the likelihood of this occurring would be the same under Alternative 2 With TUCP Without VA as under the No Action Alternative due to the identical flows.

During the late September to mid-November peak adult migration period, the modeled monthly average flows under Alternative 2 With TUCP Without VA would be the same as the No Action Alternative except in November of above normal water years when the modeled monthly average flow would be 41 cfs lower under Alternative 2 With TUCP Without VA (363 cfs) than the No Action Alternative (403 cfs; Table O-174). In December and January, the only substantial difference in modeled monthly average flow (greater than 5%) between the two alternatives would be a reduction of 51 cfs in December in below normal water years from 931 cfs under the No Action Alternative to 880 cfs under Alternative 2 With TUCP Without VA. Neither the November flow difference nor the December flow difference would have impacts on modeled monthly average water temperature at Lewiston Dam in the respective water year types (Figure O-20 and Figure O-21), and there would be no impacts on water temperature suitability for coho salmon migration and holding relative to the No Action Alternative.

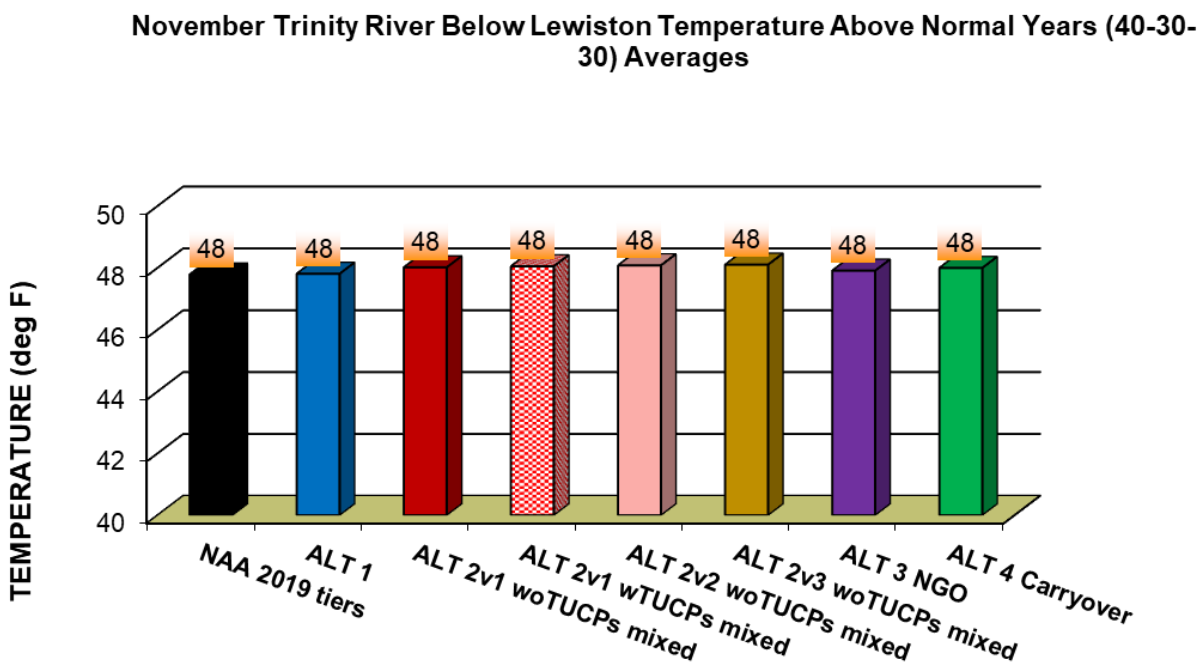


Figure O-20. Modeled November Average Water Temperature in the Trinity River below Lewiston Dam in Above Normal Water Years

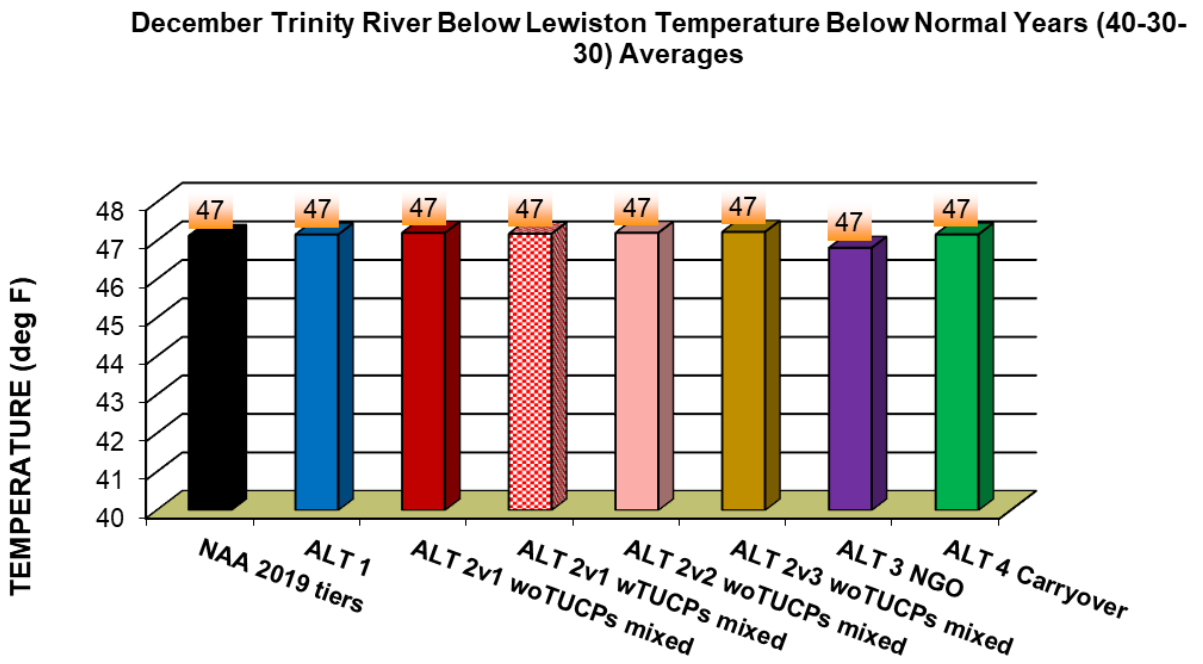


Figure O-21. Modeled December Average Water Temperature in the Trinity River below Lewiston Dam in Below Normal Water Years

Alternative 2 Without TUCP Without VA

Monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to flows under Alternative 2 With TUCP Without VA (Table O-175) so impacts to coho adult upstream migration and holding from flow changes and water temperature would be the same as Alternative 2 With TUCP Without VA and the No Action Alternative.

Alternative 2 Without TUCP With Delta VA

Monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Delta VA would be very similar to flows under Alternative 2 With TUCP Without VA (Table O-176). During the upstream migration and holding period, the differences in modeled monthly average flow and associated differences in modeled monthly average water temperature would have the same impacts on migrating and holding coho salmon as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Systemwide VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be very similar to flows under Alternative 2 With TUCP Without VA (Table O-177). During the upstream migration and holding period, the differences in modeled monthly average flow and associated differences in modeled monthly average water temperature would have the same impacts on migrating and holding coho salmon as those described for Alternative 2 With TUCP Without VA.

O.5.27 Upper Klamath-Trinity River Fall-run Chinook Salmon ESU

O.5.27.1 Trinity River

Spawning and Egg/Alevin Incubation

Most fall-run Chinook salmon in the Trinity River spawn from late October to December, with a peak in spawning occurring in November (Myers et al. 1998, Leidy and Leidy 1984). Optimal spawning temperatures for spawning are reported to be less than 55.4°F (Moyle 2002). At optimal intragravel temperatures (43–54°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another 4–6 weeks (Moyle 2002). In the Trinity River, fall-run Chinook salmon incubation and emergence typically occurs from December through late February (Leidy and Leidy 1984). The effects of flow and water temperature on fall-run Chinook salmon spawning and egg/alevin incubation may therefore occur from approximately mid-October through February.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, modeled monthly average flows in the Trinity River below Lewiston Dam would be at least 5% lower than the No Action Alternative only in November of above normal water years, in December of below normal water years, and in February of wet water years (Table O-174). Modeled monthly average flows under Alternative 2 With TUCP Without VA would increase by at least 5% in February and March of above normal

water years compared with the No Action Alternative. The November flow decrease would occur during the primary fall-run Chinook salmon spawning period and the December and February flow decreases, as well as the February flow increase, would occur during the egg/alevin incubation period. The monthly flow differences would have minor effects on the availability or suitability of spawning and egg/alevin incubation habitat for fall-run Chinook salmon relative to the No Action Alternative. Under Alternative 2 With TUCP Without VA, like the No Action Alternative, the variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

Modeled monthly average flow in November of above normal water years would decrease from 403 cfs under the No Action Alternative to 363 cfs under Alternative 2 With TUCP Without VA (Table O-174), which may benefit spawning fall-run Chinook salmon by increasing WUA for spawning adults in the primary spawning reach from Lewiston Dam to North Fork Trinity River compared with the No Action Alternative (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999; Rupert et al. 2017a, 2017b). Comparative effects on spawning suitability would vary in downstream reaches, with a decrease in spawning WUA from North Fork Trinity River to South Fork Trinity River and an increase in spawning WUA from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In all reaches of the Trinity River, the effects of flow changes on spawning suitability are likely to vary spatially with channel confinement and incision (Goodman et al. 2018). Where the channel is naturally unconfined and not overly incised and where channel restoration has removed remnant riparian berms and reduced legacy channel confinement and incision, a stronger positive relationship between flow and salmonid habitat suitability, particularly for flows of approximately 300–1,200 cfs, can be expected than in areas of greater channel confinement (see Section O.4.24.1.1 for a detailed discussion). This is mainly a result of increasing habitat area, which provides more space for redds and reduces the risk of redd superimposition by later-spawning salmonids. Although the effects of flow changes on spawning suitability are likely to vary spatially with channel confinement and incision at higher flows (Goodman et al. 2018), the effects of channel geometry are expected to be negligible for flows in the range of 350–400 cfs.

In December of below normal water years modeled monthly average flow in the Trinity River below Lewiston Dam would decrease from 931 cfs under the No Action Alternative to 880 cfs under Alternative 2 With TUCP Without VA (Table O-174). In February of wet water years, modeled monthly average flows would decrease from 1,843 cfs under the No Action Alternative to 1,706 cfs under Alternative 2 With TUCP Without VA. The December and February decreases would occur during the fall-run Chinook salmon egg/alevin incubation period. The lower monthly average flows in December and February under Alternative 2 With TUCP Without VA would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative, especially in areas with a confined channel where relatively minor changes in flow have little influence on water depth or velocity, and no effects on egg/alevin incubation suitability are expected.

Modeled monthly average flow in the Trinity River below Lewiston Dam would increase in February of above normal water years from 1,194 cfs under the No Action Alternative to 1,390 cfs under Alternative 2 With TUCP Without VA and in March of above normal water years from 1,021 cfs under the No Action Alternative to 1,095 cfs under Alternative 2 With TUCP Without

VA (Table O-174). The February flow increase would occur during the fall-run Chinook salmon egg/alevin incubation period but is not expected to change redd hydraulics or other conditions that may affect incubation suitability. No effects on egg/alevin incubation suitability are expected.

Modeled monthly average water temperature in the Trinity River below Lewiston Dam in November of above normal water years and December of below normal water years would not differ from the No Action Alternative (Figure O-18 and Figure O-19, respectively), while in February of wet water years the modeled monthly average water temperature may increase slightly under Alternative 2 With TUCP Without VA compared to the No Action Alternative (Figure O-17). November water temperatures under Alternative 2 With TUCP Without VA would remain well below the upper water temperature objective of 56°F (Table O-11) to protect spawning fall-run Chinook salmon in the reach from Lewiston Dam to the North Fork Trinity River (Asarian et al. 2023). In December and February, water temperatures from Lewiston Dam to North Fork Trinity River would remain below the 50°F (10°C) upper optimum limit recommended by USEPA (2001, as cited in Carter 2005) in all water year types to support fall-run Chinook salmon incubation and emergence (Asarian et al. 2023). Water temperatures under Alternative 2 With TUCP Without VA would have negligible effects on fall-run Chinook salmon spawning and incubation suitability compared with the No Action Alternative.

Compared with the No Action Alternative, the effects of seasonal operations under Alternative 2 With TUCP Without VA would likely have minor impacts on the availability and suitability of fall-run Chinook salmon spawning and incubation habitat in the Trinity River. Overall, the impacts in the reaches most heavily used by spawning fall-run Chinook salmon would likely be negligible or slightly beneficial, with spatial variability related to the impacts of channel geometry on habitat suitability.

<u>Alternative 2 Without TUCP Without VA</u>

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be very similar to flows under Alternative 2 With TUCP Without VA, except for a larger increase (greater than 5%) in February of above normal water years (Table O-175). During the fall-run Chinook salmon spawning and incubation period, modeled monthly average flows in November of above normal water years, December of below normal water years, and February of wet water years would be at least 5% less than flows under the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on fall-run Chinook salmon spawning and incubation as those described for Alternative 2 With TUCP Without VA. Compared with the No Action Alternative, the increased average flow in February of above normal water years would result in negligible changes in spawning WUA for fall-run Chinook salmon (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Overall, the impacts of seasonal operations under Alternative 2 Without TUCP Without VA on the availability and suitability of fall-run Chinook salmon spawning and incubation habitat would likely be negligible or slightly beneficial compared with the No Action Alternative, with spatial variability related to the impacts of channel geometry on habitat suitability.

Alternative 2 Without TUCP With Delta VA

Monthly average flows in the Trinity River under Alternative 2 Without TUCP With Delta VA would be nearly identical to flows under Alternative 2 With TUCP Without VA (Table O-176). Compared with the No Action Alternative, substantial (greater than 5%) reductions in monthly average flow under Alternative 2 Without TUCP With Delta VA would occur in November of above normal water years, December of below normal water years, and February of wet water years.

Like Alternative 2 With TUCP Without VA, the November and December flow decreases would not result in measurable changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-18 and Figure O-19). Modeled monthly average water temperature in the Trinity River below Lewiston in February of wet water years may increase slightly under Alternative 2 Without TUCP With Delta VA compared to the No Action Alternative (Figure O-17). The potential impacts on the availability and suitability of fall-run Chinook salmon spawning and egg/alevin incubation habitat that may result from the small differences in modeled monthly average flow and water temperature relative to the No Action Alternative would be the same as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Systemwide VA

Monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be very similar to flows under Alternative 2 Without TUCP Without VA, but with a larger increase in February of above normal water years (Table O-177). Modeled monthly average flows in November of above normal water years, December of below normal water years, and February of wet water years would be at least 5% less than flows under the No Action Alternative. These differences in monthly average flow and associated differences in water temperature would have the same impacts on fall-run Chinook salmon spawning and incubation as those described for Alternative 2 With TUCP Without VA.

In February of above normal water years, modeled monthly average flow would increase by 131 cfs from 1,194 cfs under the No Action Alternative to 1,325 cfs under Alternative 2 Without TUCP With Systemwide VA (Table O-177). This increase would not be expected to have measurable impacts on depth, velocity, or substrate that could affect suitability for incubating fall-run Chinook salmon eggs/alevins. Similarly, the February flow increase would not result in measurable changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-18) and there would be no change in the temperature suitability for incubating fall-run Chinook salmon eggs/alevins relative to the No Action Alternative.

Juvenile Rearing and Emigration

In the Trinity River, fall-run Chinook salmon fry emerge from the gravel beginning in December and most emergence is complete by mid-April. Natural juvenile fall-run Chinook salmon primarily outmigrate as sub-yearlings from the Trinity River. Hatchery releases of fall-run Chinook salmon also include mostly smolts released primarily in late spring and fall. Peak outmigration occurs in March, April, and May but can extend to July based on monitoring in the lower Trinity River near the town of Willow Creek (Moyle 2002, Chesney and Yokel 2003). The effects of flow and water temperature on rearing and emigrating fall-run Chinook salmon may therefore occur primarily from December through July.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, modeled monthly average flows in the Trinity River below Lewiston Dam would be more than 5% lower than the No Action Alternative in December of below normal water years, and in February of wet water years (Table O-174). In February and March of above normal water years, modeled monthly average flows under Alternative 2 With TUCP Without VA would increase by at least 5% compared with the No Action Alternative.

The December, February, and March differences may have spatially variable impacts on the availability and suitability of juvenile rearing and emigration habitat for fall-run Chinook salmon. The decrease in modeled monthly average flow in December of below normal water years from 931 cfs under the No Action Alternative to 880 cfs under Alternative 2 With TUCP Without VA would result in a decrease in fry WUA and an increase in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, an increase in both fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and a decrease in fry WUA and an increase in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The monthly average flow reductions in February of wet water years from 1,843 to 1,706 cfs would result in reductions in WUA for fry and juvenile fall-run Chinook salmon from Lewiston Dam to Dutch Creek, small increases in fry and juvenile WUA from Dutch Creek to North Fork Trinity River, a slight decrease in fry WUA and a small increase in juvenile WUA from North Fork Trinity River to South Fork Trinity River, and little to no change in fry and juvenile WUA from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

The modeled monthly flow increase in February of above normal water years from 1,194 cfs under the No Action Alternative to 1,390 cfs under Alternative 2 With TUCP Without VA would result in an increase in Chinook salmon fry WUA and decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek and a decrease in both fry and juvenile WUA in the reaches from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In March of above normal water years, the increase in modeled monthly average flow from 1,021 cfs under the No Action Alternative to 1,095 cfs under Alternative 2 With TUCP Without VA would result in an increase in Chinook salmon fry WUA and decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, a decrease in both fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and an increase in fry WUA and very small decrease in juvenile WUA from South Fork Trinity River to Weitchpec.

Where the channel is naturally unconfined and not overly incised and in locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships and spawning WUA in some restored areas may exhibit a stronger positive relationship to flow up to approximately 3,500 cfs (Cooper-Hertel et al. 2022). Consequently, fall-run Chinook salmon WUA in all reaches is likely to vary spatially with channel confinement and incision and in restored areas may be greater than described in U.S. Fish and Wildlife Service and Hoopa Valley Tribe (1999). See Section

O.4.24.1.1 for additional details. The potential changes in WUA for fall-run Chinook salmon fry and juveniles may have minor, short-term impacts on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the rearing period and in some reaches of the Trinity River.

In December of below normal water years and February and March of above normal water years, differences in modeled monthly average flows between Alternative 2 With TUCP Without VA and the No Action Alternative would not result in changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-19). In February of wet water years, reductions in modeled monthly average flows between Alternative 2 With TUCP Without VA and the No Action Alternative may slightly increase modeled monthly average water temperatures below Lewiston Dam compared to the No Action Alternative (Figure O-17). In December of below normal water years, February of wet water years, and February and March of above normal water years, the modeled monthly average water temperatures at Trinity River below Lewiston Dam under Alternative 2 With TUCP Without VA would remain well below the 62.6°F water temperature objective for emigrating juvenile fall-run Chinook salmon recommended for normal and wetter water year types and the 68°F objective recommended for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that water temperatures in December, February, and March would remain below both objectives under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating fall-run Chinook salmon under Alternative 2 With TUCP Without VA relative to the No Action Alternative.

Compared with the No Action Alternative, seasonal operations under Alternative 2 With TUCP Without VA would likely have negligible impacts on the availability and suitability of fall-run Chinook salmon juvenile rearing and emigration habitat in the Trinity River. The impacts would vary spatially due to the impacts of channel geometry on habitat suitability.

<u>Alternative 2 Without TUCP Without VA</u>

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to Alternative 2 With TUCP Without VA and impacts on rearing and emigrating juvenile fall-run Chinook salmon would be the same.
Alternative 2 Without TUCP With Delta VA.

Compared with the No Action Alternative, substantial (greater than 5%) reductions in monthly average flow under Alternative 2 Without TUCP With Delta VA would occur in February of wet water years. Effects on spring-run Chinook salmon spawning and egg/alevin incubation at these times would be nearly identical to those under Alternative 2 With TUCP Without VA. Increased flow (greater than 5%) in February of above normal water years would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative is not expected to affect egg/alevin incubation suitability.

These differences in monthly average flow and associated differences in water temperature would have the same effects on spring-run Chinook salmon juvenile rearing and emigration as those described for Alternative 2 With TUCP Without VA for February.

Alternative 2 Without TUCP With Systemwide VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be nearly identical to flows under Alternative 2 Without TUCP With Delta VA and the impacts on fall-run Chinook salmon would be the same.

Adult Upstream Migration and Holding

Adult fall-run Chinook salmon typically enter the Trinity River from September through October (Moyle et al. 2015). Two to four weeks after river entry, adults have made it to the primary spawning reach which extends from Lewiston Dam downstream to the confluence of the North Fork Trinity River. After entering freshwater, fall-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically ranges from the third week of September through November, peaking in October (Chensey and Knechtle 2012). The effects of flow and water temperature on migrating and pre-spawning fall-run Chinook salmon adults may therefore occur from August through November.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, seasonal operations in the Trinity River are expected to provide similar habitat conditions for fall-run Chinook salmon during the upstream migration and pre-spawning period to the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish including Chinook salmon. During the August–November fall-run Chinook salmon upstream migration and pre-spawning period there would be no differences in modeled monthly average flow between the two alternatives from August–October and greater than 5% reduction in flows in November of above normal years (Table O-174). The minor differences in November are not expected to result in changes in habitat suitability for migrating and holding fall-run Chinook salmon, as modeled monthly average flows would decrease only from 403 to 363 cfs towards the end of the migration period. During the entirety of the adult upstream migration and holding period, modeled monthly average flows would be approximately 300 cfs or greater in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and habitat to support pre-spawning fall-run Chinook salmon.

Under both alternatives, September through October flows would maintain suitable water temperatures for adult upstream migration (would not exceed 56°F from August through October at Douglas City [RM 93.7]; Table O-11) (Asarian et al. 2023). Under Alternative 2 With TUCP Without VA, suitability for adult fall-run Chinook salmon upstream migration and holding would be the same as under the No Action Alternative.

Alternative 2 Without TUCP Without VA

During August–November when fall-run Chinook salmon are migrating upstream and preparing to spawn, modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to flows under Alternative 2 With TUCP Without VA, with no differences in modeled monthly average flow between the two alternatives from August through November and greater than 5% reduction in flows in above

normal years in November (Table O-175). The monthly average flows and associated monthly average water temperatures would have the same impacts on migrating and holding fall-run Chinook salmon as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Delta VA

During the August–November fall-run Chinook salmon upstream migration and pre-spawning period, modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Delta VA would be nearly identical to flows under Alternative 2 With TUCP Without VA, with no differences in modeled monthly average flow between the two alternatives from August through November and greater than 5% reduction in flows in above normal years in November (Table O-176). The monthly average flows and associated monthly average water temperatures would have the same impacts on fall-run Chinook salmon during the upstream migration and pre-spawning period as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Systemwide VA

During the August-November fall-run Chinook salmon upstream migration and pre-spawning period, modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be nearly identical to flows under Alternative 2 With TUCP Without VA, with no differences in modeled monthly average flow between the two alternatives from August through November and greater than 5% reduction in flows in above normal years in November (Table O-177). The monthly average flows and associated monthly average water temperatures would have the same impacts on fall-run Chinook salmon during the upstream migration and pre-spawning period as those described for Alternative 2 With TUCP Without VA.

O.5.28 Klamath Mountains Province Steelhead DPS

O.5.28.1 Trinity River

Monthly average flows in the Trinity River below Lewiston Dam would generally be similar under Alternative 2 to flows under the No Action Alternative. Considering the full simulation period, minor differences in monthly average flows between Alternative 2 and the No Action Alternative would occur in November through April of some water year types, with most differences less than 5%. Monthly average flows under the four phases of Alternative 2 would be very similar, with some differences (greater than 5%) from the No Action Alternative occurring in November through March of some water year types among the Alternative 2 phases.

Spawning and Egg/Alevin Incubation

Spawning across run types in the Trinity River may occur anytime from December through May so effects of flow and water temperature on spawning may occur during this period.

Steelhead eggs and alevins across run types in the Trinity River may be present in the gravel from December through June, so effects of flow and water temperature on steelhead eggs and alevins may occur during this period.

Potential Changes to Steelhead from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, modeled monthly average flows in the Trinity River below Lewiston Dam would be at least 5% lower than the No Action Alternative within the spawning and incubation period in November of above normal water years, December of below normal water years, and in February of wet water years (Table O-174). Like all other phases of Alternative 2, monthly average flows averaged across the full simulation period would be slightly less in November through April than monthly average flows under the No Action Alternative.

Reduced monthly average flow in November of above normal water years from 403 cfs to 363 cfs would have little to no change in spawning WUA for steelhead in the reach from Lewiston to North Fork Trinity and from South Fork Trinity to Weitchpec and negligible increases in the reach from North Fork Trinity to South Fork Trinity (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

Reduced monthly average flow in December of below normal water years from 931 cfs to 880 cfs would have little to no change in spawning WUA for steelhead in the reach from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999)(steelhead spawning WUA estimates are not available at discharges over 800 cfs from Lewiston Dam to Dutch Creek).

Reduced monthly average flow in February of wet water years from 1,843 cfs to 1,706 cfs would have little to no change in spawning WUA for steelhead in the reach from Dutch Creek to South Fork Trinity and negligible decreases from South Fork Trinity to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

Increased monthly average flow in February of above normal water years from 1,194 cfs to 1,390 cfs would have little to no change in spawning WUA for steelhead in the reach from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

Increased monthly average flow in March of above normal water years from 1,021 cfs to 1,095 cfs would have little to no change in spawning WUA for steelhead in the reach from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

The December flow decreases would not result in measurable changes in modeled average water temperature in the Trinity River below Lewiston Dam (Appendix F, Figure F.2.11-1-1) and average water temperatures under Alternative 2 With TUCP Without VA would remain well below the upper water temperature objective of 56°F to protect spawning salmonids in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11).u

In February of wet water years, monthly average flows in the Trinity River below Lewiston Dam would be reduced from 1,843 cfs under the No Action Alternative to 1,706 cfs under Alternative 2 With TUCP Without VA. In February and March of wet water years, monthly average flows would slightly increase under Alternative 2 With TUCP Without VA relative to the No Action Alternative. The higher monthly average flows in February and March under Alternative 2 With

TUCP Without VA in above normal water years would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative, especially in areas with a confined channel where minor changes in flow have relatively little influence on water depth or velocity. However, the February flow reduction under Alternative 2 With TUCP Without VA could slightly increase the risk of dewatering of redds constructed in January compared to the No Action Alternative. This is because average monthly flows under Alternative 2 With TUCP Without VA would decrease by 157 cfs from January (1,863 cfs) to February (1,706 cfs), in contrast to the No Action Alternative under which flows would decrease by only 29 cfs from January (1,872 cfs) to February (1,843 cfs) (Table O-174).

Modeled average water temperature in the Trinity River below Lewiston Dam in February and March of wet water years may increase slightly under Alternative 2 With TUCP Without VA compared to the No Action Alternative (Figure O-17) but would remain below the 50°F upper suitability limit recommended by Washington State Department of Ecology (WDOE) (2002, as cited in Carter 2005) and would support steelhead incubation and emergence.

Alternative 2 Without TUCP Without VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to flows under Alternative 2 With TUCP Without VA (Table O-175) so impacts to steelhead spawning, egg incubation, and fry emergence habitat from flow changes and water temperature would be the same as Alternative 2 With TUCP Without VA. Alternative 2 Without TUCP With Delta VA

With regard to spawning, egg incubation, and fry emergence, modeled monthly average flows in the Trinity River under Alternative 2 Without TUCP With Delta VA would be nearly identical to flows under Alternative 2 With TUCP Without VA in November and February (Table O-176). Compared to the No Action Alternative, substantial (greater than 5%) reductions in monthly average flow under Alternative 2 Without TUCP With Delta VA would occur in November of above normal water years and February of wet water years nearly the same as Alternative 2 With TUCP Without VA. Flow increases are predicted to occur in February of above normal water years nearly the same as Alternative 2 With TUCP Without VA.

Monthly average water temperature in the Trinity River below Lewiston Dam in February and March of wet water years may increase slightly under Alternative 2 Without TUCP With Delta VA compared to the No Action Alternative (Figure O-17). The potential impacts on the availability and suitability of steelhead spawning and egg/alevin incubation habitat that may result from the small differences in monthly average flow and water temperature relative to the No Action Alternative would be the same as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Systemwide VA

Monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be nearly identical to flows under Alternative 2 Without TUCP With Delta VA and impacts from flow and temperature changes would be the same for spawning, egg incubation, and fry emergence habitat as Alternative 2 Without TUCP With Delta VA. Juvenile Rearing and Emigration

Rearing or moving (migrating or redistributing) fry and/or juveniles can occur downstream of Lewiston Dam any time of year with three peak emigration times in March, May/June, and October/November.

Potential Changes to Steelhead from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, modeled monthly average flows in the Trinity River below Lewiston Dam would be more than 5% lower than the No Action Alternative in November of above normal water years, in December of below normal water years, and in February of wet water years (Table O-174). These differences may have spatially variable impacts on the availability and suitability of juvenile rearing and emigration habitat for steelhead. The decrease in modeled monthly average flow in November of above normal water years from 403 cfs under the No Action Alternative to 363 cfs under Alternative 2 With TUCP Without VA (Table O-174) would result in overall minor increases in observed and predicted WUA for fry and juvenile steelhead across reaches of the Trinity River from Lewiston Dam to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Similarly, the decrease in monthly average flow in December of below normal water years from 931 cfs under the No Action Alternative to 880 cfs under Alternative 2 With TUCP Without VA would result in overall minor increases in observed and predicted WUA for fry and juvenile steelhead from Lewiston Dam to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

In contrast, the reduced monthly average flows in February (from 1,843 cfs to 1,706 cfs) of wet water years would result in reductions in WUA for fry and increases for juvenile steelhead from Lewiston Dam to Dutch Creek; negligible increases for fry and juvenile WUA from Dutch Creek to North Fork Trinity River; a slight decrease in fry WUA and little to no change in juvenile WUA from North Fork Trinity River to South Fork Trinity River; and decreases in fry and little to no change in juvenile WUA from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). These changes in WUA for steelhead fry and juveniles may have minor, short-term impacts on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the year and in wet water years in some reaches of the Trinity River.

Modeled flow increases in February and March of above normal water years would result in minor increases in estimated fry and juvenile WUA in the reach between Lewiston Dam and Dutch Creek, minor decreases for both in the reach from Dutch Creek to South Fork Trinity, and minor increases in fry WUA and minor decreases in juvenile WUA in the reach from South Fork Trinity to Weitchpec.

In November of above normal water years, December of below normal water years, and February and March of above normal water years, differences in modeled monthly average flows between Alternative 2 With TUCP Without VA and the No Action Alternative would not result in changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-18 and Figure O-19, respectively). In February of wet water years, differences in monthly average flows between Alternative 2 With TUCP Without VA and the No Action Alternative may slightly increase modeled monthly average water temperatures compared to the No Action Alternative (Figure O-17). In November, December, February, and March of the

aforementioned water year types, modeled monthly average water temperatures at Trinity River below Lewiston Dam under Alternative 2 With TUCP Without VA would remain well below the 59°F water temperature objective for emigrating salmon recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in November, December, February, and March would remain below the 59°F objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating steelhead under Alternative 2 With TUCP Without VA relative to the No Action Alternative. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 2 With TUCP Without VA through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in some months at downstream locations in some water year types under Alternative 2 With TUCP Without VA, water temperatures and the potential impacts on steelhead would not differ from the No Action Alternative.

Alternative 2 Without TUCP Without VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to flows under Alternative 2 With TUCP Without VA so impacts to steelhead juvenile rearing and emigration from flow changes and temperature would be the same as Alternative 2 With TUCP Without VA (Table O-175).
Alternative 2 Without TUCP With Delta VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Delta VA would be nearly identical to flows under Alternative 2 With TUCP Without VA for November of above normal water years, February of wet water years, and February of above normal water years and would result in the same minor increases in fry and juvenile WUA in November of above normal water years and the same spatially variable minor increases and decreases in fry and juvenile WUA in February of wet and above normal water years (Table O-176). Modeled temperature changes would also be the same as Alternative 2 With TUCP Without VA for November of above normal water years, February of wet water years, and February of above normal water years and no adverse temperature impacts are expected to juvenile rearing and emigration from Alternative 2 Without TUCP With Delta VA relative to the No Action Alternative..

Alternative 2 Without TUCP With Systemwide VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would be nearly identical to flows under Alternative 2 Without TUCP With Delta VA (Table O-177) and therefore impacts would be the same as Alternative 2 Without TUCP With Delta VA. Adult Upstream Migration and Holding

Consistent adult monitoring data are limited by environmental conditions and challenges in overlapping populations with different run timing, kelting or “runbacks”, and half pounders but summer/fall steelhead (stream-maturing steelhead) are thought to return from the ocean about April through November and hold for varying lengths of time in the Klamath-Trinity watershed

(Moyle et al. 2017; Moyle et al. 2015; Pinnix et al 2007). Winter steelhead (ocean-maturing steelhead) can return from the ocean about November through March (Moyle et al. 2017; Moyle et al. 2015; Pinnix et al 2007). Given the overlapping run timings and varying life history strategies, adults at various stages of maturation can enter the Klamath-Trinity watershed, hold in Trinity River, and/or migrate up or down Trinity River and into tributaries in any month of the year.

Potential Changes to Steelhead from Seasonal Operations

Alternative 2 With TUCP Without VA

Under Alternative 2 With TUCP Without VA, seasonal operations in the Trinity River are expected to provide similar habitat conditions for steelhead migration and holding to the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish including steelhead. Modeled monthly average flows in the Trinity River below Lewiston Dam would be more than 5% lower than the No Action Alternative in November of above normal water years, December of below normal water years, and February of wet water years (Table O-174). These differences may result in minor, short-term changes in habitat conditions but monthly average flows would be equal to or greater than 300 cfs in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and holding habitat to support pre-spawning steelhead.

Modeled monthly average flows in August and September are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 2 With TUCP Without VA as under the No Action Alternative (Table O-174). Under both alternatives, modeled average August and September flows of 760 cfs in wet water years and 863 cfs in all other water year types would maintain suitable water temperatures for adult upstream migration (would not exceed 56°F from August through October at Douglas City [RM 93.7]; Table O-11) in the Trinity River at Lewiston Dam (Figure O-17). Although downstream warming during August and September could result in unsuitable water temperatures for migrating steelhead at some locations, the likelihood of this occurring would be the same under Alternative 2 With TUCP Without VA as under the No Action Alternative due to the identical flows.

The monthly average flows under Alternative 2 With TUCP Without VA would be the same as the No Action Alternative except in November of above normal water years when the modeled monthly average flow would be 41 cfs lower under Alternative 2 With TUCP Without VA (363 cfs) than the No Action Alternative (403 cfs; Table O-174). In December and January, the only substantial difference in modeled monthly average flow (greater than 5%) between the two alternatives would be a reduction of 51 cfs in December in below normal water years from 931 cfs under the No Action Alternative to 880 cfs under Alternative 2 With TUCP Without VA. Neither the November flow difference nor the December flow difference would have measurable impacts on modeled monthly average water temperature at Lewiston Dam in the respective water year types (Figure O-20 and Figure O-21) and there would be no impacts on water temperature suitability for steelhead migration and holding relative to the No Action Alternative.

Alternative 2 Without TUCP Without VA

Monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP Without VA would be nearly identical to flows under Alternative 2 With TUCP Without VA (Table O-175) so Alternative 2 Without TUCP Without VA would have the same impacts on migrating and holding steelhead as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Delta VA

Monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Delta VA would be very similar to flows under Alternative 2 With TUCP Without VA (Table O-176) but without the modeled increase in average monthly flow in December of below normal water years or the small increase in flow in March of above normal water years. These differences are negligible for adult migration and holding habitat and overall differences in modeled monthly average flow and associated differences in modeled monthly average water temperature would have the same impacts on migrating and holding steelhead as those described for Alternative 2 With TUCP Without VA.

Alternative 2 Without TUCP With Systemwide VA

Modeled monthly average flows in the Trinity River below Lewiston Dam under Alternative 2 Without TUCP With Systemwide VA would nearly identical to flows under Alternative 2 Without TUCP With Delta VA (Table O-177) and the impacts to migrating and holding adult steelhead would be the same.

O.5.29 Northern DPS Green Sturgeon

O.5.29.1 Trinity River

Spawning and Egg Incubation

Northern DPS green sturgeon adults spawn primarily from March through July, though most spawning takes place from April to June (O.1.2.5.1, *Green Sturgeon, Northern* DPS). Northern DPS green sturgeon eggs hatch approximately a week after fertilization, and optimal temperatures for incubation range from 51.8–62.6°F (Van Eenennaam et al. 2005). The effects analysis period for incubating eggs is considered to be the same as the spawning period due to the short incubation period and includes March through July.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Modeled flows in the Trinity River downstream of Lewiston Dam under Alternative 2 would generally be similar to flows under the No Action Alternative. Flows under each phase of Alternative 2 would be very similar as under the No Action Alternative, with minor differences among the phases occurring in November through April of some water year types and most differences being less than 5%. A few months in certain water year types between November and March would have differences in modeled monthly average flows greater than 5% relative to the No Action Alternative.

Green sturgeon are only known to occur within the lower 43 miles of the Trinity River ranging as far upstream as Grays Falls near Burnt Ranch, approximately 70 miles downstream of Lewiston Dam (Benson et al. 2007). Water temperature and habitat conditions within this section of the

Trinity River are heavily influenced by several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries). Results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations are unlikely to have a detectable influence on the water temperature suitability for spawning and egg incubation of green sturgeon.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be more than 5% higher than the No Action Alternative during the spawning period in March of above normal water years (Table O-174). The March flow increase would occur during the green sturgeon spawning and egg incubation period. This very small increase in flows in above normal water years would be negligible for spawning habitat and egg incubation because flows would still be above 1,876 cfs and would increase slightly relative to the No Action Alternative.
- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be identical to Alternative 2 With TUCP Without VA in the spawning season so impacts to spawning, egg incubation, and emergence would be the same as Alternative 2 With TUCP Without VA.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would not differ from the No Action Alternative more than 5% in any month or water year type during the spawning period (Table O-176).
- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would no differ from the No Action Alternative more than 5% in any month or water year type during the spawning period (Table O-177).

Larval and Juvenile Rearing and Emigration

The northern DPS green sturgeon spawning period is from March through July, and the larval period is considered to be from March through September. The juvenile stage of green sturgeon begins when metamorphosis of the larva is complete, typically about 45 days after hatching and approximately up to 2 cm TL. Juveniles (up to 150 cm TL) typically slowly migrate downstream, and rear in the lower Klamath River for up to a year or until approximately their first summer, and optimal growth temperatures range from 59–66.2°F (Moyle 2002; Mayfield and Cech, Jr. 2004). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near Burnt Ranch to the Klamath River Estuary (Section O.1.2.5.1, *Green Sturgeon, Northern DPS*). The effects analysis period for larval and juvenile life stages in the Trinity River should be considered April to September.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 2 would generally be similar to flows under the No Action Alternative. Minor differences in monthly average flows between Alternative 2 and the No Action Alternative would occur in November through April of some water year types, with most differences being less than 5%. Flows under each phase of Alternative 2 would be very similar, but minor differences among the phases would occur in November through April of some water year types and nearly all differences would be less than 5%.

Green sturgeon larvae and juveniles are only known to occur within the lower 43 miles of the Trinity River, and after hatching, they begin to migrate downstream. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of between 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations would not likely have a detectable influence on the water temperature suitability for larval and juvenile rearing and emigration of green sturgeon.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be almost identical to the No Action Alternative during the larval and juvenile rearing period from April through September and would correspond to the No Action Alternative flows, which are currently managed to improve habitat conditions for anadromous fish (Table O-174). Alternative 2 With TUCP Without VA monthly average flows would have no impacts to negligible impacts on larval and juvenile rearing and emigration of green sturgeon when compared with the No Action Alternative.
- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be almost identical to the No Action Alternative during larval and juvenile rearing period from April through September and would correspond to the No Action Alternative flows, which are currently managed to improve habitat conditions for anadromous fish (Table O-175). Alternative 2 Without TUCP Without VA monthly average flows would have no impacts to negligible impacts on larval and juvenile rearing and emigration of green sturgeon when compared with the No Action Alternative.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be almost identical to the No Action Alternative during larval and juvenile rearing period from April through September and would correspond to the No Action Alternative flows, which are currently managed to improve habitat conditions for anadromous fish (Table O-176). Alternative 2 Without TUCP With Delta VA monthly average flows would have no impacts to negligible impacts on larval and juvenile rearing and emigration of green sturgeon when compared with the No Action Alternative.

- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be almost identical to the No Action Alternative during the larval and juvenile rearing period from April through September and would correspond to the No Action Alternative flows, which are currently managed to improve habitat conditions for anadromous fish (Table O-177). Alternative 2 Without TUCP With Systemwide VA monthly average flows would have no impacts to negligible impacts on larval and juvenile rearing and emigration of green sturgeon when compared with the No Action Alternative.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Trinity River from the Klamath River Estuary as early as February to make their way upstream to spawn in deep pools from the lower section of the mainstem Trinity River to the confluence with the Klamath River upstream approximately 43 miles to Gray's Falls near Burnt Ranch. After spawning, the adults remain in mainstem river pools for varying amounts of time, representing distinct migration patterns. Directly after spawning, 25% emigrate back to the Klamath River Estuary and ocean, but freshwater residency may last up to 199 days (Moyle 2002, Section O.1.3.2.5, *Green Sturgeon, Northern DPS*). With the extended adult holding period, the effects analysis period of flow and water temperature on adult upstream immigration, holding, and emigration may occur from February through December.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 2 would generally be similar to flows under the No Action Alternative. Under Alternative 2, a reduction in flows greater than 5% would occur in February of wet years and in November of above normal years for all Alternative 2 phases, and in December of below normal years for Alternative 2 phases without VA compared to the No Action Alternative.

Green sturgeon adults are only known to occur within the lower 43 miles of the Trinity River, and they have variable freshwater residence time (Benson et al. 2007). Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations are not likely to have a detectable influence on the water temperature suitability for migration and holding of adult green sturgeon.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be similar to or less than the No Action Alternative from February to December (Table O-174). During the green sturgeon upstream migration and holding period, a greater than 5% flow reduction would occur under the No Action Alternative in February of wet years, in November of above normal years, and in

December of below normal years. The decrease in flow in February of wet years would be negligible because releases would still average 1,706 cfs. Monthly average flows during the summer and fall months under Alternative 2 With TUCP Without VA compared with the No Action Alternative would be identical and would provide adequate flows for downstream movement and holding in pool habitats. Reduced flows under Alternative 2 With TUCP Without VA in November and December would remain above 300 cfs, and this reduction would likely have a negligible effect on green sturgeon migration movements.

- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be nearly identical to Alternative 2 With TUCP Without VA (Table O-175) and impacts on adult green sturgeon would be the same.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With VA, monthly average flows would be similar or less to the No Action Alternative from February to December (Table O-176). During the green sturgeon upstream migration and holding period, a greater than 5% flow reduction would occur compared to the No Action Alternative in February of wet years, in November of above normal years, and in December of below normal years. The decreased flow in wet years during would be negligible because releases would average 1,693 cfs. Monthly average flows during the summer and fall months under Alternative 2 Without TUCP With Delta VA compared with the No Action Alternative would be identical, except for reduced flows in November of above normal years, and would provide adequate flows for downstream movements and holding in pool habitats. Reduced flows under Alternative 2 With TUCP Without VA in November of above normal water years would remain above 300 cfs, and this reduction would likely have a negligible effect on green sturgeon migration movements.
- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP Systemwide VA, monthly average flows would be nearly identical to Alternative 2 Without TUCP With Delta VA(Table O-176) and therefore impacts to adult green sturgeon would be the same.

O.5.30 Eulachon

O.5.30.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean

Spawning and Egg Incubation

Eulachon adults spawn from December through May, with peak spawning occurring in March and April (O.1.2.6 *Eulachon*). Eulachon eggs hatch in 20 to 40 days depending on water temperature, with cooler temperatures leading to longer incubation times. Spawning is reported to occur at temperatures from 39 to 50°F; colder temperatures may stop migration (National Marine Fisheries Service 2017a). The effects analysis period for eulachon spawning and egg incubation is December through June.

Potential Changes to Eulachon from Seasonal Operations

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek

and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature and habitat conditions within this section Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries). Previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 2 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for spawning and egg incubation of eulachon in the Lower Klamath River.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and December during below normal water years (Table O-174) during the eulachon spawning and egg incubation period. There would also be an increase in flows of greater than 5% in February and March of above normal water years. The modeled flow reductions would likely be negligible for spawning and egg incubation as flows would average 1,706 cfs in February of wet water years and 880 cfs in December of below normal water years. These modeled flows changes will likely have a negligible impact on flows in the lower Klamath River where eulachon spawning and egg incubation will take place.
- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and December during below normal water years (Table O-174) during the eulachon spawning and egg incubation period. There would also be an increase in flows of greater than 5% in February and March of above normal water years. These flow changes of greater than 5% would occur during the eulachon spawning and egg incubation period. The reduction in flows would not likely impact eulachon spawning and egg incubation as flows would remain an average of 1,699 cfs in February of wet water years and 880 cfs in December in below normal water years. These modeled flows changes will likely have a negligible impact on flows in the lower Klamath River where eulachon spawning and egg incubation will take place.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years (Table O-174) during the eulachon spawning and egg incubation period. There would also be a modeled increase in flows of greater than 5% in February of above normal water years. The reduction in flows would likely be negligible for spawning and egg incubation as flows would remain an average of 1,693 cfs in February of wet water years. These modeled flows changes would be rare and will likely have a negligible impact on flows in the lower Klamath River where eulachon spawning and egg incubation will take place.

- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and more than 5% higher in February of above normal water years (Table O-174) during the eulachon spawning and egg incubation period. The reduction in flows would not likely impact eulachon spawning and egg incubation as flows would average 1,698 cfs in February of wet water years. These modeled flows changes will likely have a negligible impact on flows in the lower Klamath River where eulachon spawning and egg incubation will take place.

Larval Emigration

Eulachon spawning period is from December through May and eggs hatch in 20 to 40 days, so the larval period is considered to be January through June. After hatching, larval eulachon are quickly carried out to the ocean by river currents (Scott and Crossman 1973). Larval eulachon only remain in the Klamath River for about 5 days until they are washed out to sea. Larvae live on their yolk sac reserves after hatching —they do not feed while in fresh water (Gustafson et al. 2022). Effects of flow and water temperature on eulachon larvae may occur from January through June in the Klamath River.

Potential Changes to Eulachon from Seasonal Operations

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Eulachon larvae are washed downstream to the ocean immediately after hatching. Water temperature and habitat conditions within this section Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 2 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for eulachon larval emigration.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and 5% higher in February and March of above normal water years (Table O-174) during the eulachon larval emigration period. The modeled reduction in flows would likely be negligible for larval emigration as flows would only decrease 137 cfs with an average of 1,706 cfs in February in wet water years, a small proportion of the total flow in the lower Klamath River. This modeled flow change would have a negligible impact on flows in the lower Klamath River where eulachon spawning and egg incubation occurs.

- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and 5% higher in February and March of above normal

water years (Table O-174)during the eulachon larval emigration period. The reduction in flows would not likely impact larval emigration as flows would only decrease 143 cfs with an average of 1,699 cfs in February of wet water years, a small proportion of the total flow in the lower Klamath River. This modeled flow change would have a negligible impact on flows in the lower Klamath River where eulachon spawning and egg incubation occurs.

- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and 5% higher in February of above normal water years (Table O-174) during the eulachon larval emigration period. The reduction in flows would likely be negligible for larval emigration as flows would only decrease 150 cfs with an average of 1,693, a small proportion of the total flow in the lower Klamath River. This modeled flow change would have a negligible impact on flows in the lower Klamath River where eulachon spawning and egg incubation occurs.
- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and 5% higher in February of above normal water years (Table O-174)during the eulachon larval emigration period. The reduction in flows would not likely impact larval emigration as flows would only decrease 144 cfs and average 1,698 cfs in February in wet water years, a small proportion of the total flow in the lower Klamath River. This modeled flow change would have a negligible impact on flows in the lower Klamath River where eulachon spawning and egg incubation occurs.

Adult Upstream Migration

The spawning migration period for adult eulachon in the Klamath River begins in December and continues until May, with peak migration occurring in March and April (Yurok Tribal Fisheries Program 1998; Larson and Belchik 1998, Section O.1.2.6). Eulachon distribution in the Trinity River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Eulachon are broadcast spawners most commonly over sand, though spawning substrates can range from silt, sand or gravel to cobble and detritus (California Department of Fish and Wildlife 2010; National Marine Fisheries Service 2017a). Eulachon usually die after spawning. The effects analysis period for eulachon adult upstream migration is December through May.

Potential Changes to Eulachon from Seasonal Operations

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature and habitat conditions within this section of the Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley

Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations are unlikely to have a detectable influence on the water temperature suitability for eulachon adult upstream migration.

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and December during below normal water years and 5% higher in February and March of above normal water years (Table O-174) during the eulachon adult migration period. The modeled reduction in flows would likely be negligible for eulachon adult migration as flows would still average 1,706 cfs, a decrease of only 137 cfs, in February of wet water years and average 880 cfs, a decrease of only 51 cfs, in December of below normal water years, a small proportion of the total flow in the lower Klamath River. These modeled flow change would have a negligible impact on flows in the lower Klamath River where eulachon adult migration occurs.
- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and December during below normal water years and greater than 5% higher in February of above normal water years and 5% higher in February and March of above normal water years (Table O-174) during the eulachon adult migration period. The reduction in flows would likely be negligible for eulachon adult migration as flows would still average 1,699 cfs, a decrease of only 143 cfs, in February of wet water years and average 880 cfs, a decrease of only 51 cfs, in December of below normal water years, a small proportion of the flow in the lower Klamath River. These modeled flow change would have a negligible impact on flows in the lower Klamath River where eulachon adult migration occurs.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and more than 5% higher in February of above normal water years (Table O-174) during the eulachon adult migration period. The reduction in flows would likely be negligible for eulachon adult migration as flows would still average 1,693 cfs in wet water years, only a decrease of 150 cfs, a small proportion of flow in the Klamath River. This modeled flow change would have a negligible impact on flows in the lower Klamath River where eulachon adult migration occurs..
- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and 5% higher in February of above normal water years (Table O-174) during the eulachon adult migration period. The reduction in flows would likely be negligible for eulachon adult migration as flows would still average 1,698 cfs in February in wet water years, a decrease of only 144 cfs, a small proportion of the flow in the lower Klamath River. This modeled flow change would have a negligible impact on flows in the lower Klamath River where eulachon adult migration occurs..

O.5.31 Coastal Cutthroat Trout

O.5.31.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean

Spawning and Egg Incubation

Generally, spawning of anadromous and resident coastal cutthroat trout may occur from September to April (Moyle 2002). Coastal cutthroat trout are associated with shaded streams and instream cover with water temperatures below 64°F, while preferred temperatures range from 48–54°F, with spawning temperatures of 43–63°F (Moyle 2002). Spawning habitat is typically found in headwater streams with 1–3 feet/sec flow velocities and unembedded small- to medium-sized gravel (0.08–4 inches) (Moyle 2002). Embryos hatch about 6–7 weeks following incubation and alevins emerge 1–2 weeks thereafter (Moyle 2002).

The effects analysis period for coastal cutthroat trout spawning and egg incubation is September through June.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would be lower than or similar to flows under the No Action Alternative with a greater than 5% decrease in flows in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for spawning and egg incubation as Trinity River flows do not impact tributaries where coastal cutthroat trout spawn and modeled flow reductions occur outside the spawning and egg incubation period.
- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years, November in above normal water years, and December during below normal water years and greater than 5% higher in February and March of above normal water years (Table O-174). These reductions in flows would be negligible for spawning and egg incubation as Trinity River flows do not impact tributaries where coastal cutthroat trout spawn and modeled flow reductions occur outside the spawning and egg incubation period.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). These reduction in flows would likely be negligible for spawning and egg incubation as Trinity River flows do not impact tributaries where coastal cutthroat trout spawn and modeled flow reductions occur outside the spawning and egg incubation period.

- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). The reduction in flows would likely be negligible for spawning and egg incubation as Trinity River flows do not impact tributaries where coastal cutthroat trout spawn and modeled flow reductions occur outside the spawning and egg incubation period.

Seasonal operations under the various phases of Alternative 2 are not expected to impact suitable habitat conditions for coastal cutthroat trout spawning and egg incubation in the Trinity River. Compared to the No Action Alternative, no adverse impacts on coastal cutthroat trout are expected.

Juvenile Rearing and Emigration

Juvenile coastal cutthroat trout may spend anywhere from one to three years in freshwater to rear. Cutthroat fry are typically associated with slow water velocities (less than 1 foot/sec, while they prefer <0.3 feet/sec), and trout are typically found in shaded streams with instream cover and water temperatures below 64°F, while preferred temperatures range from 48–54°F (Moyle 2002).

For the amphidromous life history, most coastal cutthroat trout leave their streams for the summer months and return to overwinter in fresh water, even as non-spawning fish (Moyle 2002). During outmigration, many of the trout migrate to estuaries or lagoons and if they do go to the ocean, they remain close to the coast (Moyle 2002). In a Klamath River tributary, yearling and older cutthroat emigration occurred mainly between April and June (Moyle 2002). For individuals that emigrated to an estuary, Wallace (2004) found that the residence time within the estuary ranged from 5 to 89 days, with a mean of 27 days. Resident coastal cutthroat trout will remain in freshwater their entire lives, rather than emigrating to a lagoon or estuary or the ocean.

The effects analysis period for coastal cutthroat trout juvenile rearing and emigration is April through June for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would lower than or similar to flows under the No Action Alternative with a greater than 5% decrease in flows in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for coastal cutthroat trout juvenile rearing and emigration as flows would still average 1,706 cfs in February of wet water years, 363 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows would occur in February and March of above normal water years, but this is not anticipated to have an impact on coastal cutthroat trout juvenile rearing and emigration.

- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for coastal cutthroat trout juvenile rearing and emigration as flows would still average 1,699 cfs in February of wet water years, 362 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows would occur in February and March of above normal water years, but this is not anticipated to have an impact on coastal cutthroat trout juvenile rearing and emigration.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). These reduction in flows would likely be negligible for coastal cutthroat trout juvenile rearing and emigration would still average 1,693 cfs in February of wet water years and 337 cfs in November of above normal water years.
- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). The reduction in flows would likely be negligible for coastal cutthroat trout juvenile rearing and emigration as flows would still average 1,698 cfs in wet water years and 339 cfs in above normal water years.

Seasonal operations under the various phases of Alternative 2 are expected to maintain suitable habitat conditions for coastal cutthroat trout juvenile rearing and emigration in the Trinity River. Compared to the No Action Alternative, changes in the availability or suitability of coastal cutthroat trout juvenile rearing and emigration habitat would be minimal and adverse impacts on coastal cutthroat trout would be negligible.

Adult Holding and Migration

Migration of coastal cutthroat trout to freshwater typically occurs between August and October between the ages of one and five (Moyle 2002). While most anadromous salmonids die after completing spawning, coastal cutthroat may survive spawning, re-enter the ocean, and return the following year(s) to spawn up to five times (Moyle 2002). Overwintering coastal cutthroat trout prefer pools with cover (e.g., logs, undercut banks, boulders) (Moyle 2002).

The effects analysis period for coastal cutthroat trout adult holding and migration is August through October for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout. Because operational changes in flows beyond 5% are only expected in November, December and February, there would be no adverse impacts across all Alternative 2 phases on amphidromous coastal cutthroat trout and the following analysis applies to resident coastal cutthroat trout.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would lower than or similar to flows under the No Action Alternative with a greater than 5% decrease in flows in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for coastal cutthroat trout adult holding and migration as flows would still average 1,706 cfs in February of wet water years, 363 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows is modeled in February and March of above normal water years, but this is not anticipated to have an impact on coastal cutthroat trout adult holding and migration.

- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for coastal cutthroat trout adult holding and migration as flows would still average 1,706 cfs in February of wet water years, above 363 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows is modeled in February and March of above normal water years, but this is not anticipated to have an impact on coastal cutthroat trout adult holding and migration.

- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). These reduction in flows would likely be negligible for coastal cutthroat trout adult holding and migration and would still average 1,693 cfs in February in wet water years and 337 cfs in November of above normal water years.

- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). The reduction in flows would likely be negligible for adult holding and migration as flows would still average 1,698 cfs in February of wet water years and 339 cfs in November of above normal water years.

Seasonal operations under the various phases of Alternative 2 are expected to maintain suitable habitat conditions for coastal cutthroat trout adult holding and migration in the Trinity River for all life history strategies. Compared to the No Action Alternative, substantial changes in the availability or suitability of coastal cutthroat trout adult holding and migration habitat would be minimal and negligible adverse impacts on coastal cutthroat trout are expected.

O.5.32 Brown Trout

O.5.32.1 Trinity River

Spawning and Egg Incubation

Brown trout spawn in fall and winter, most commonly in November and December in California (Moyle 2002). Trout typically mature and spawn in their second or third year, but they may wait longer (7 or 8 years) (Moyle 2002). Adults begin selecting spawning locations when water temperatures are between 42.8–50°F (Moyle 2002). Spawning habitat is comprised of pea- to walnut-sized gravel in less turbulent waters, which are typically found at pool tailouts (Moyle 2002). Embryos hatch in 7–8 weeks (ranging from 4–21 weeks), with alveins emerging 3–6 weeks later, depending on water temperature.

The effects analysis period for brown trout spawning and egg incubation is November through April.

Potential Changes to Brown Trout from Seasonal Operations

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would lower than or similar to flows under the No Action Alternative with a greater than 5% decrease in flows in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for spawning and egg incubation as flows would still average 1,706 cfs in February of wet water years,363 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows is modeled in February and March of above normal water years, but this is not anticipated to have an impact on brown trout spawning and egg incubation.
- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for spawning and egg incubation as flows would still average 1,699 cfs in February of wet water years, 362 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows is modeled in February and March of above normal water years, but this is not anticipated to have an impact on brown trout spawning and egg incubation.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February wet water years and November of above normal water years (Table O-174). These reduction in flows would likely be negligible for spawning and egg incubation as flows would still average 1,693 cfs in February of wet water years and 337 cfs in November of above normal water years. A greater than 5% increase in flows is modeled in February of above normal water years, but this is not anticipated to have an impact on brown trout spawning and egg incubation.

- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). The reduction in flows would likely be negligible for spawning and egg incubation as flows would still average 1,698 cfs in February of wet water years and 339 cfs in November of above normal water years. A greater than 5% increase in flows is modeled in February of above normal water years, but this is not anticipated to have an impact on brown trout spawning and egg incubation.

Seasonal operations under the various phases of Alternative 2 are expected to maintain suitable habitat conditions for brown trout spawning and egg incubation in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout spawning and egg incubation habitat would be minimal resulting in negligible adverse impacts on brown trout.

Juvenile Rearing and Emigration

The ideal temperature range for brown trout is between 53.6–68°F, with optimal growth between 62.6–64.4°F; they can survive for only short period at higher temperatures up to 84.2°F (Moyle 2002). Cold temperatures reduce brown trout's ability to effectively capture prey: when temperatures reduced from 58.5°F to 42.3°F the foraging effectiveness reduced from 96% to 53% (Watz and Piccolo 2010, as cited in Asarian et al., 2023).

In California, brown trout reach 2–3 inches in length their first year, 5–6 inches in their second year, 8–11 inches in their third, and 14–16 inches in their fourth year (Moyle 2002). Fry rear in edge-water habitat that is slow and shallow (<12 inches deep), with juveniles selecting riffles and pools with deeper water (20–30 inches), higher velocities (0.3–1.3 feet/second), and cover from overhead, rocks, and logs (Moyle 2002). It is uncertain the degree to which brown trout exhibit an anadromous life history in the Trinity River, with juveniles emigrating to the ocean, or are riverine (potamodromous) with juveniles emigrating further downstream while continuing to remain in freshwater. In Ireland, where they are native, brown trout juveniles emigrated to brackish or marine habitats throughout the year, with distinct seasonal peeks in spring (March through June) and fall (September through December) (Wynne et al., 2023).

The effects analysis period for brown trout juvenile rearing and emigration is January through December.

Potential Changes to Brown Trout from Seasonal Operations

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would lower than or similar to flows under the No Action Alternative with a greater than 5% decrease in flows in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for juvenile rearing and emigration as flows would still average 1,706 cfs in February of wet water years, 363 cfs in November of above normal water years, and880 cfs in December of below normal water years. A greater than 5% increase in flows is modeled in February and March of above normal water years, but this is not anticipated to have an impact on brown trout juvenile rearing and emigration.

- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for juvenile rearing and emigration as flows would still average 1,699 cfs in February of wet water years, 362 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows is modeled in February and March of above normal water years, but this is not anticipated to have an impact on brown trout juvenile rearing and emigration.
- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). These reduction in flows would likely be negligible for juvenile rearing and emigration as flows would still average 1,693 cfs in February of wet water years, 337 cfs in November of above normal water years. A greater than 5% increase in flows is modeled in February of above normal water years, but this is not anticipated to have an impact on brown trout juvenile rearing and emigration.
- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February of wet water years and November of above normal water years (Table O-174). The reduction in flows would likely be negligible for juvenile rearing and emigration as flows would still be average 1,698 cfs in February of wet water years and 339 cfs in November of above normal water years. A greater than 5% increase in flows is modeled in February of above normal water years, but this is not anticipated to have an impact on brown trout juvenile rearing and emigration.

Seasonal operations under the various phases of Alternative 2 are expected to maintain suitable habitat conditions for brown trout juvenile rearing and emigration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout juvenile rearing and emigration habitat would be minimal and would have negligible adverse impacts on brown trout.

Adult Holding and Migration

Upstream migration occurs in fall and winter, prior to spawning, which most commonly occurs in November and December. Sullivan and Hilemean (2018) noted a shift in migration timing on the Trinity River to later in the season following the implementation of the Record of Decision (ROD) flows (2005-2011, 2017), as compared to the between baseline Pre-ROD flows (1982–2002). In rivers, adults will hold in a wide range of habitats, but are often associated with low velocity pools ranging from 2.3–11.5 feet deep that have cover (Moyle 2002).

The effects analysis period for brown trout adult holding and migration is January through December with migration primarily in November and December.

Potential Changes to Brown Trout from Seasonal Operations

- **Alternative 2 With TUCP Without VA:** Under Alternative 2 With TUCP Without VA, monthly average flows would lower than or similar to flows under the No Action Alternative with a greater than 5% decrease in flows in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for migrating and holding adults as flows would still be average 1,706 cfs in February of wet water years, 363 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows modeled in February and March of above normal water years, but this is not anticipated to have an impact on brown trout adult migration and holding.

- **Alternative 2 Without TUCP Without VA:** Under Alternative 2 Without TUCP Without VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years, November in above normal water years, and December during below normal water years (Table O-174). These reductions in flows would likely be negligible for migrating and holding adults as flows would still average 1,706 cfs in February of wet water years, 363 cfs in November of above normal water years, and 880 cfs in December of below normal water years. A greater than 5% increase in flows modeled in February of above normal water years, but this is not anticipated to have an impact on brown trout adult migration and holding.

- **Alternative 2 Without TUCP With Delta VA:** Under Alternative 2 Without TUCP With Delta VA, monthly average flows would be greater than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). These reduction in flows would likely be negligible for adult migration and holding as flows would still average 1,693 cfs in February of wet water years and 337 cfs in November of above normal water years. A greater than 5% increase in flows is modeled in February of above normal water years, but this is not anticipated to have an impact on brown trout adult migration and holding.

- **Alternative 2 Without TUCP With Systemwide VA:** Under Alternative 2 Without TUCP With Systemwide VA, monthly average flows would be more than 5% lower than the No Action Alternative in February in wet water years and November of above normal water years (Table O-174). The reduction in flows would likely be negligible for adult migration and holding as flows would still average 1,698 cfs in February of wet water years and above 339 cfs in November of above normal water years. A greater than 5% increase in flows is modeled in February of above normal water years, but this is not anticipated to have an impact on brown trout adult migration and holding.

Seasonal operations under the various phases of Alternative 2 are expected to maintain suitable habitat conditions for brown trout adult migration and holding in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout adult migration and holding habitat would be minimal and would have negligible adverse impacts on brown trout.

O.5.33 Trinity Reservoir Species

O.5.33.1 Trinity Reservoir

Spawning and Egg Incubation

Coldwater fish species (rainbow trout, brown trout, Kokanee, and landlocked Chinook salmon) in the lake generally migrate into tributaries to spawn either during from December through March (rainbow trout), November–December (brown trout), or August through April (kokanee). Populations of rainbow trout, brown trout, and Kokanee are sustained through a combination of natural reproduction and fish hatchery stocking practices. Landlocked Chinook salmon do not typically reproduce (Perales et al. 2015) and are supported by annual stocking practices.

Warmwater fish species (smallmouth bass, largemouth bass, white catfish, and brown bullhead) typically rely on habitat in the lake during all life stages. In general, smallmouth and largemouth bass spawn from April through July in shallow water (1.5 feet to 6.0 feet deep) along the lake margins at water temperatures ranging from 55°F to 75°F (Moyle 2002). These nests are vulnerable to differences in water levels. Rapid drops in water levels may cause guarding males to abandon the nests, increase predation, and limit water circulation and dissolved oxygen levels around the eggs (USFWS 1983, Habitat Suitability Information: Smallmouth Bass, FWS/OBS-82/10.36). White catfish spawning typically occurs during June and July when water temperatures exceed 68°F, but spawning can sometimes extend into September; spawning occurs in sandy substrate adjacent to cover (e.g., rocks, wood, or aquatic vegetation) and eggs hatch in about a week (Moyle 2002). Brown bullhead spawn from May through mid-July and will build their nests in sand or gravel near cover (Moyle 2002). Warmwater fish species in Trinity Lake are currently self-sustaining through natural reproduction.

The effects analysis period for coldwater fish species spawning and egg incubation is August through April. The effects analysis period for warmwater fish species spawning and egg incubation is April through September.

CalSim 3 monthly average volume in Trinity Reservoir shows that modeled reservoir volume would not change more than 5% for any of the Alternative 2 phases across all months (Table O-178 through Table O-181); therefore, impacts to reservoir species spawning and incubation would be negligible across all four phases of Alternative 2.

Larval and Juvenile Rearing and Emigration

Rainbow trout fry emerge three to four weeks after fertilization and will remain in the gravel for about 2–3 weeks (Moyle 2002, USFWS 1984, Habitat Suitability Information: Rainbow Trout, FWS/OBS-82/10.60). Juvenile rainbow trout may spend two summers in their natal stream and two summers in a reservoir or lake before maturing. Brown trout fry typically hatch in twomonths, though it can range from one to five months depending on water temperature, and larvae will emerge from the gravel around 1 month later. Juveniles will spend several years in tributaries before emigrating to the reservoir where they will become sexually mature (Moyle 2002, Belica 2007).

Smallmouth and largemouth bass fry prefer shallow water and are vulnerable to fluctuations in water levels. These fry hatch in two to seven days and then spend another week in the nest.

Larval bass stay in shallow water on the edge of vegetation (Moyle 2002). Rapid drops in water levels may cause stranding. Juvenile bass tend to live in deeper water habitats with submerged shelter (e.g., logs or boulders). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002).

The effects analysis period for both coldwater and warmwater fish species larval and juvenile rearing and emigration is January through December.

CalSim 3 monthly average volume in Trinity Reservoir shows that modeled reservoir volume would not change more than 5% for any of the Alternative 2 phases across all months (Table O-178 through Table O-181); therefore, impacts to reservoir species larval and juvenile rearing and emigration would be negligible across all four phases of Alternative 2.

Adult Holding

The life expectancy of rainbow trout can be four to eight years in northern California lake populations. After maturing, resident rainbow trout will migrate upstream to spawn in tributaries. They can spawn annually and will quickly move back downstream to the reservoir or lake (Moyle 2002), moving to cooler, deeper waters during the summer months (Belica 2007). Brown trout typically become sexually mature at age two or three and have been found as old as can live for up to 9 years in California, spawning several times during their life (Moyle 2002, Belica 2007). Brown trout will use varying habitats within the reservoir and will also move to cooler waters in the summer habitats (Belica 2007).

Warmwater species will remain in the reservoir their entire lives. Smallmouth bass prefer narrow bays and upstream ends of reservoirs or along the shore where rocky shelves are present at a depth of 1–10m (Moyle 2002). They become sexually mature at age three to four and typically live less than seven years (USFWS 1983, Habitat Suitability Information: Smallmouth Bass, FWS/OBS-82/10.36). Age of largemouth bass in California reservoirs is four to five years and they typically spawn during their second season (Moyle 2002). Adult bass tend to prefer deeper, colder waters in lakes and reservoirs in areas with vegetation and other forms of cover (USFWS 1983b, Habitat Suitability Information: Largemouth Bass, FWS/OBS-82/10.16). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002). They become sexually mature at age three and will spawn multiple times during their lifetime of up to eight to 10 years (Moyle 2002).

The effects analysis period for both coldwater and warmwater fish species adult holding is January through December.

CalSim 3 monthly average volume in Trinity Reservoir shows that modeled reservoir volume would not change more than 5% for any of the Alternative 2 phases across all months (Table O-178 through Table O-181); therefore, impacts to reservoir species adult migration and holding would be negligible across all four phases of Alternative 2.

O.5.34 Central Valley Reservoir Species

O.5.34.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations

Shasta Reservoir

Warmwater Species

Reductions in Shasta Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-166.

- For **Alternative 2 With TUCP Without VA**, WSE reductions of 6 feet or more would be similar to those under the No Action Alternative during all months except May, in which there would be eight fewer reductions under Alternative 2 With TUCP Without VA. These results indicate that Alternative 2 With TUCP Without VA would have a beneficial effect on warmwater species in Shasta Reservoir.
- For **Alternative 2 Without TUCP Without VA**, WSE reductions of 6 feet or more would be similar to those under the No Action Alternative during all months except May, in which there would be nine fewer reductions under Alternative 2 Without TUCP Without VA. These results indicate that Alternative 2 Without TUCP Without VA would have a beneficial effect on warmwater species in Shasta Reservoir.
- For **Alternative 2 Without TUCP Delta VA**, WSE reductions of 6 feet or more would be similar to those under the No Action Alternative during all months except May, in which there would be nine fewer reductions under Alternative 2 Without TUCP Delta VA. These results indicate that Alternative 2 Without TUCP Delta VA would have a beneficial effect on warmwater species in Shasta Reservoir.
- For **Alternative 2 Without TUCP Systemwide VA**, WSE reductions of 6 feet or more would be similar to those under the No Action Alternative during all months except May and June, in which there would be eight and six fewer reductions, respectively, under Alternative 2 Without TUCP Systemwide VA. These results indicate that Alternative 2 Without TUCP Systemwide VA would have a beneficial effect on warmwater species in Shasta Reservoir.

Overall, Alternative 2 would have beneficial effects on warmwater species in Shasta Reservoir.

Coldwater Species

Shasta Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-166.

- For **Alternative 2 With TUCP Without VA**, storage would be similar to that of the No Action Alternative during most months of wet, above normal, and below normal water years. Storage would be 5.1-5.7% greater under Alternative 2 With TUCP Without VA during July through October of dry water years and 7.6-33.8% higher in all months evaluated in critically dry water years, representing large beneficial effects to coldwater reservoir species.
- For **Alternative 2 Without TUCP Without VA**, storage would be similar to that of the No Action Alternative during most months of wet, above normal, below normal, and dry water years. In critical water years, storage under Alternative 2 Without TUCP Without VA would be up to 12.6% higher than storage under the No Action Alternative, representing a beneficial effect to coldwater reservoir species.
- For **Alternative 2 Without TUCP Delta VA**, storage would be similar to that of the No Action Alternative during most months of wet, above normal, below normal, and dry water years. In critical water years, storage under Alternative 2 Without TUCP Without VA would be up to 15.5% higher than storage under the No Action Alternative, representing a beneficial effect to coldwater reservoir species.
- For **Alternative 2 Without TUCP Systemwide VA**, storage would be similar to that of the No Action Alternative during most months of wet, above normal, below normal, and dry water years. In critical water years, storage under Alternative 2 Without TUCP Without VA would be up to 14.4% higher than storage under the No Action Alternative, representing a beneficial effect to coldwater reservoir species.

Overall, Alternative 2 would have beneficial effects on coldwater species in Shasta Reservoir, particularly in critically dry water years.

Whiskeytown Reservoir

Warmwater Species

Reductions in Whiskeytown Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-167. These results indicate that, for all 4 phases of Alternative 2, there would be no or negligible difference in WSE month-over-month reductions of 6 feet or more relative to the No Action Alternative. Therefore, there would be negligible effects of Alternative 2 on warmwater species in Whiskeytown Reservoir.

Coldwater Species

Whiskeytown Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-168.

For all phases of Alternative 2, end-of-month storage volume would be similar to that of the No Action Alternative. These results indicate that Alternative 2 would have negligible effects on coldwater species in Whiskeytown Reservoir.

Folsom Reservoir

Warmwater Species

Reductions in Folsom Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-169. There would be zero to four more reductions under Alternative 2 than the No Action Alternative depending on month and phase. However, the low frequency of these reductions is not expected to have a negative effect on warmwater species.

Coldwater Species

Folsom Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-170.

- For **Alternative 2 With TUCP Without VA**, storage would be similar to that of the No Action Alternative during wet, above normal, below normal, and dry water years. Storage would be 4.1-10.9% higher under Alternative 2 With TUCP Without VA during July through October of critical water years, representing a beneficial effect to coldwater reservoir species.
- For **Alternative 2 Without TUCP Without VA**, storage would be similar to that of the No Action Alternative during most months of wet, above normal, below normal, and dry water years. In critical water years, storage under Alternative 2 Without TUCP Without VA would be 7.4-12.7% % lower than storage under the No Action Alternative, representing a negative effect to coldwater reservoir species.
- For **Alternative 2 Without TUCP Delta VA**, storage would be similar to that of the No Action Alternative during most months of wet, above normal, below normal, and dry water years. In critical water years, storage under Alternative 2 Without TUCP Without VA would be 9.1-13.7% lower than storage under the No Action Alternative, representing a negative effect to coldwater reservoir species.
- For **Alternative 2 Without TUCP Systemwide VA**, storage would be similar to that of the No Action Alternative during wet and below normal water years. In above normal, dry, and critical water years, storage under Alternative 2 Without TUCP Without VA would be up to 11.9% lower than storage under the No Action Alternative, representing a negative effect to coldwater reservoir species.

Overall, Alternative 2 effects on coldwater species would be mixed depending on phase, but mostly negative, particularly in critically dry water years and under Alternative 2 Without TUCP Systemwide VA.

New Melones Reservoir

Warmwater Species

Reductions in New Melones Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Melones 2.

For all phases of Alternative 2, there would be zero to two fewer reductions of 6 feet or more than under the No Action Alternative depending on month. The low frequency of these reductions is not expected to provide a beneficial effect on warmwater species in New Melones Reservoir.

Coldwater Species

New Melones Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-172.

- For **Alternative 2 With TUCP Without VA**, **Alternative 2 Without TUCP Without VA**, and **Alternative 2 Without TUCP Delta VA**, end-of month storage would be similar to storage under the No Action Alternative during all months evaluated and in all water year types.
- For **Alternative 2 Without TUCP Systemwide VA**, storage would be up to 5.7% higher in dry water years and up to 9.4% lower in critical water years.

These results suggest that there would be negligible effects under Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, and Alternative 2 Without TUCP Delta VA, and both small beneficial and negative effects of Alternative 2 Without TUCP Systemwide VA on coldwater fish species in New Melones Reservoir.

O.5.35 Delta-Mendota Canal / California Aqueduct Species

O.5.35.1 Potential Changes to Delta-Mendota Canal/California Aqueduct Species from Seasonal Operations

Water from the Delta is diverted through the California Aqueduct and Delta-Mendota Canal and held for off-stream storage (e.g., in San Luis Reservoir) and there is no coldwater habitat in the Delta-Mendota Canal. Therefore, no analysis of coldwater habitat was conducted. Warmwater species such as black basses and striped bass support recreational fishing in the California Aqueduct. Water velocity in the canal is not specifically managed to support or enhance recreational fisheries. Increases in water velocity may decrease water temperatures and flowing water for species, improving conditions; while decreases in water velocity may increase water temperatures and lead to stagnant water for species, diminishing conditions.

Differences in flows and velocity under the four phases of Alternative 2, compared to the No Action Alternative, are expected to be minimal thus, impacts to species present are not expected to change.

O.5.36 San Luis Reservoir Species

O.5.36.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations

Warmwater Species

Reductions in San Luis Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects. Please see Section O.4.33.2, *Methods,* for details on the methods used in this analysis. Results are presented in Table O-173.

- For **Alternative 2 With TUCP Without VA**, there would be between one more and 22 fewer reductions than under the No Action Alternative depending on month, representing a beneficial effect to warmwater reservoir species.
- For **Alternative 2 Without TUCP Without VA**, there would be between more and 26 fewer reductions than under the No Action Alternative depending on month, representing a beneficial effect to warmwater reservoir species.
- For **Alternative 2 Without TUCP Delta VA**, there would be between five more and 22 fewer reductions than under the No Action Alternative depending on month, representing a slight negative and larger beneficial effect to warmwater reservoir species.
- For **Alternative 2 Without TUCP Systemwide VA**, there would be between six more and 23 fewer reductions than under the No Action Alternative depending on month, representing a slight negative and larger beneficial effect to warmwater reservoir species.

Overall, the four phases of Alternative 2 would predominantly have no or beneficial effects on warmwater species in San Luis Reservoir, with some slight negative effects under the two phases with VAs.

O.5.37 Southern Resident Killer Whale

O.5.37.1 Nearshore Pacific Ocean on the California Coast

Changes in water operations under the alternatives could have the potential to affect Chinook salmon prey for Southern Resident Killer Whale (Southern Resident) relative to the No Action Alternative. Outlined below are expected changes in Southern Residents' prey. Four lines of evidence were used (Salmort, XT, CVPIA SIT LCM, and DPM), and Attachment F.7, *Change in Abundance Estimate of Central Vally Chinook Salmon Available to Southern Resident Killer Whales*, provides detailed results of all models and analyses.

- Based on the lines of evidence, **Alternative 2 Without TUCP Without VAs** is predicted to have an annual abundance of about 232,725 Chinook salmon that survive to adulthood or about 3,494,361 pounds of Chinook salmon biomass in the ocean available as potential prey to Southern Residents. This is about 26 less Chinook salmon or 385 pounds less than the No Action Alternative. This is likely a negligible difference in Chinook salmon and biomass available to Southern Residents for prey between the No Action Alternative and Alternative 2 Without TUCP Without VAs.
- Based on the lines of evidence, **Alternative 2 With TUCP Without VAs** is predicted to have an annual abundance of about 232,730 Chinook salmon that survive to adulthood or about 3,494,444 pounds of Chinook salmon biomass in the ocean available as potential prey to Southern Residents. This is about 20 less Chinook salmon or 302 pounds less than the No Action Alternative. This is likely a negligible difference in Chinook salmon and biomass available to Southern Residents for prey between the No Action Alternative and Alternative 2 With TUCP Without VAs.
- Based on the lines of evidence, **Alternative 2 Without TUCP with Delta VAs** is predicted to have an annual abundance of about 232,722 Chinook salmon that survive to adulthood or about 3,494,314 pounds of Chinook salmon biomass in the ocean available as potential prey to Southern Residents. This is about 29 less Chinook salmon or 432 pounds less than the No Action Alternative. This is likely a negligible difference in Chinook salmon and biomass available to Southern Residents for prey between the No Action Alternative and Alternative 2 Without TUCP with Delta VAs.
- Based on the lines of evidence, **Alternative 2 Without TUCP with Systemwide VAs** is predicted to have an annual abundance of about 232,931 Chinook salmon that survive to adulthood or about 3,497,453 pounds of Chinook salmon biomass in the ocean available as potential prey to Southern residents. This is about 180 more Chinook salmon or 2,707 pounds more than the No Action Alternative. This is likely a negligible difference in Chinook salmon and biomass available to Southern residents for prey between the No Action Alternative and Alternative 2 Without TUCP with Systemwide VAs.

None of the Alternative 2 phases differ greatly from the No Action Alternative but the Alternative 2 Without TUCP with systemwide VAs is the only alternative that is modeled to increase Southern Resident food relative to the No Action Alternative and therefore performs the best with regard to Southern Resident food availability out of all the Alternative 2 phases. The other three phases decrease the amount of Southern Resident food relative to the No Action Alternative but the decrease is likely negligible.

O.6 Alternative 3

Alternative 3 (Modified Natural Hydrograph) represents actions informed by discussions with some of the environmental NGOs involved in state-wide water projects. Alternative 3 combines additional Delta outflow with measures to improve drought protection and temperature management through increased reservoir carryover storage. To read more about how Alternative 3 applies a priority order for meeting downstream demands, see EI*S Chapter 3, Alternatives*.

O.6.1 Trinity River

O.6.1.1 Trinity River Flows below Lewiston Dam

CalSim 3 modeling suggests that average flow released at Lewiston Dam under Alternative 3 would generally be higher than or similar to flow under the No Action Alternative, except in below normal water years in March and wet water years in April when the Alternative 3 flows would be substantially lower (greater than 5% decrease) than the No Action Alternative flows (Table O-246). Average monthly flows under Alternative 3 would be substantially higher (greater than 5% increase) in wet years December through February; above normal years in February; and below normal years in December. Table O-246 shows that the highest flows for both alternatives are expected primarily in May and June of all water year types and during winter, spring, and early summer of wet water years and January through March and May through July of above normal water years. Throughout the full simulation period, flows on average are higher under Alternative 3 in November through March, with the greatest increases in flow (greater than 5%) December through February and a slight average decrease in flow in April.

O.6.1.2 Trinity Reservoir Storage

CalSim 3 modeling suggests that average monthly Trinity Reservoir storage under Alternative 3 would generally be higher than storage under the No Action Alternative, except in wet years April through December when Trinity Reservoir storage would be slightly lower than the No Action Alternative (Table O-247). Table O-247 shows that there are substantial increases in storage under Alternative 3 compared with the No Action Alternative (greater than 5%) in below normal years July through December; dry years August through November; and critically dry years April through January. Throughout the full simulation period, storage on average is slightly higher under Alternative 3 across all months.

Table O-246. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for the No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	373	393	1,133	1,872	1,843	2,002	1,035	4,637	3,054	1,122	760	760
Above Normal (14%)	373	403	785	1,016	1,194	1,021	552	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	931	300	606	427	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	342	720	840	912	900	682	3,598	1,820	814	834	834
ALTERNATIVE 3												
Wet (28%)	373	393	1,252	2,007	1,962	2,054	957	4,637	3,032	1,122	760	760
Above Normal (14%)	373	409	781	1,049	1,302	1,033	538	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	997	300	610	400	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	343	764	883	962	912	658	3,598	1,814	814	834	834
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	**118**	**135**	**119**	51	**-78**	0	-22	0	0	0
Above Normal (14%)	0	6	-4	33	**108**	13	-14	0	0	0	0	0
Below Normal (18%)	0	0	**65**	0	4	**-27**	0	0	0	0	0	0
Dry (24%)	0	0	0	0	0	0	0	0	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	0	1	**44**	**42**	**49**	11	-24	0	-6	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-247. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir Storage for the No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,656	1,658	1,709	1,764	1,945	2,061	2,239	2,194	2,105	2,008	1,879	1,745
Above Normal (14%)	1,496	1,518	1,581	1,661	1,837	2,005	2,165	2,079	1,992	1,880	1,702	1,546
Below Normal (18%)	1,263	1,295	1,392	1,536	1,640	1,773	1,900	1,817	1,740	1,602	1,432	1,298
Dry (24%)	1,060	1,100	1,244	1,385	1,492	1,619	1,706	1,606	1,513	1,364	1,199	1,088
Critically Dry (16%)	727	737	810	1,004	1,051	1,123	1,140	1,064	995	927	822	753
Full Simulation Period Average	1,279	1,299	1,386	1,496	1,623	1,745	1,864	1,788	1,704	1,589	1,442	1,320
ALTERNATIVE 3												
Wet (28%)	1,634	1,646	1,690	1,782	1,956	2,063	2,231	2,182	2,089	1,985	1,855	1,715
Above Normal (14%)	1,520	1,546	1,606	1,681	1,851	2,017	2,175	2,086	1,998	1,885	1,713	1,569
Below Normal (18%)	1,351	1,380	1,467	1,586	1,690	1,830	1,959	1,880	1,825	1,713	1,535	1,406
Dry (24%)	1,121	1,160	1,303	1,403	1,514	1,639	1,723	1,627	1,555	1,426	1,260	1,145
Critically Dry (16%)	790	800	873	1,069	1,101	1,173	1,206	1,132	1,066	982	889	815
Full Simulation Period Average	1,316	1,340	1,422	1,528	1,651	1,770	1,888	1,813	1,737	1,627	1,480	1,358
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-22	-11	-19	18	11	1	-8	-12	-16	-23	-25	-30
Above Normal (14%)	25	28	25	20	14	13	10	8	5	5	11	23
Below Normal (18%)	**89**	**85**	**75**	51	50	58	59	63	84	**111**	**103**	**108**
Dry (24%)	**61**	**60**	59	18	22	20	16	22	42	62	**61**	**57**
Critically Dry (16%)	**63**	**63**	**63**	**65**	51	50	**66**	**67**	**71**	**55**	**67**	**62**
Full Simulation Period Average	37	40	35	32	27	25	24	25	33	38	39	38

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.6.2 Sacramento River

Alternative 3 (Modified Natural Hydrograph) represents actions informed by discussions with some of the environmental NGOs involved in state-wide water projects. Flow releases are high during the summer to satisfy downstream demands of water users and Delta water quality, and to meet water temperature requirements of incubating Winter-run Chinook salmon eggs and alevins downstream of Keswick Dam. Subject to modeling demonstrating that operations are reasonably likely to meet the Shasta Reservoir storage requirements for water temperature management, Alternative 3 bypasses 55% of unimpaired inflow to Shasta Reservoir from December through May to achieve the monthly Delta Outflow criteria in Table 3.5-1 (see EIS Chapter 3). When the monthly Delta Outflow criteria in Table 3.5-1 is met, then releases from Shasta Reservoir that month may be reduced to 45% of unimpaired inflows from December to May. Reclamation would reduce deliveries from stored water releases from Shasta Reservoir to meet the storage requirements May through November of 3.6 MAF (EOA Storage) and 1.9 MAF (EOS Storage) on critically dry water year types, and 3.9 MAF (EOA Storage) and 2.2 MAF (EOS Storage) all other water year types (WRO 90-5). In addition, Reclamation would release unstored water to meet Delta outflow requirements described in EIS Chapter 3, Section 3.5.1.2 from December through May to the extent modeling indicates doing so was consistent with meeting these storage requirements.

O.6.2.1 Sacramento River Flows below Keswick Dam

Under Alternative 3 compared to the No Action Alternative, CalSim 3 modeling suggests monthly average flows below Keswick Dam are higher in May and December and lower April, June, and July (Table O-248). The largest decreases under Alternative 3 compared to the No Action Alternative are expected in May of critically dry water years (21%) and June (17%) of above normal water years. The largest increases under Alternative 3 compared to the No Action Alternative are expected in December of above normal water years (33%) and August of dry water years.

O.6.2.2 Sacramento River Flows below Red Bluff Diversion Dam

Under Alternative 3 compared to the No Action Alternative, CalSim 3 modeling suggests monthly average flows below Red Bluff Diversion Dam are higher in December, May, and August and lower June and July throughout the full simulation period (Table O-249Table O-249). The largest decreases in flow under Alternative 3 are expected in June and July of above normal years (18% and 15%, respectively). The largest increases in flow under Alternative 3 are expected in May of wet and above normal year types (27% and 23%, respectively) and August of dry years (23%).

O.6.2.3 Sacramento River Flows at Wilkins Slough

Under Alternative 3 compared to the No Action Alternative, CalSim 3 modeling suggests monthly average flows are higher in May and August and lower in June, July, and September throughout the full simulation period (Table O-250). The largest decreases in flow under Alternative 3 are expected in June and July of above normal years (28% and 26%, respectively). The largest increases in flow under Alternative 3 are expected in May of wet and above normal year types (35% and 37%, respectively) and August of dry years (43%).

O.6.2.4 Sacramento River Flows at Hamilton City

Under Alternative 3 compared to the No Action Alternative, CalSim 3 modeling suggests that monthly average flows are higher in May and August and lower June and July throughout the full simulation period (Table O-251). The largest decreases in flow under Alternative 3 are expected in June and July of above normal years (22% and 19%, respectively). The largest increases in flow under Alternative 3 are expected in May of wet and above normal year types (29% and 27%, respectively) and August of dry years (29%).

Table O-248. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,453	6,575	8,760	17,717	23,928	15,969	9,265	7,358	8,719	13,608	10,371	9,177
Above Normal (14%)	6,557	7,216	5,406	10,012	16,075	9,999	5,427	7,925	10,098	15,553	11,005	8,571
Below Normal (18%)	5,525	5,011	7,696	4,912	5,278	5,012	5,325	9,308	10,409	14,159	10,770	5,608
Dry (24%)	4,809	5,025	7,991	3,399	4,693	4,137	5,592	8,051	10,950	13,138	9,106	5,524
Critically Dry (16%)	4,333	4,288	3,335	3,568	4,277	3,662	3,905	7,013	9,415	10,109	7,723	5,030
Full Simulation Period Average	5,869	5,675	7,067	8,633	11,711	8,352	6,279	7,899	9,863	13,307	9,804	6,909
ALTERNATIVE 3												
Wet (28%)	7,315	6,088	8,893	18,476	24,448	16,049	9,495	9,765	7,485	13,066	9,969	8,634
Above Normal (14%)	6,676	6,360	6,669	10,432	16,113	10,260	5,671	9,915	8,393	13,335	10,757	7,815
Below Normal (18%)	5,490	5,379	8,481	5,001	5,953	5,020	4,507	8,869	9,455	12,968	11,415	5,843
Dry (24%)	4,996	5,060	8,413	3,507	4,762	4,159	4,489	7,395	10,386	13,173	11,019	5,297
Critically Dry (16%)	4,730	5,086	3,783	3,962	3,772	3,531	3,757	5,548	8,657	9,555	7,862	4,765
Full Simulation Period Average	5,946	5,604	7,603	9,010	11,919	8,397	5,942	8,381	8,850	12,550	10,255	6,597
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-138	**-486**	132	759	520	80	230	**2,407**	**-1,234**	-541	-402	**-543**
Above Normal (14%)	119	**-857**	**1,262**	420	38	261	244	**1,990**	**-1,704**	**-2,218**	-248	**-755**
Below Normal (18%)	-36	**369**	**785**	90	**674**	8	**-818**	-439	**-954**	**-1,192**	**644**	235
Dry (24%)	187	34	**421**	108	68	22	**-1,103**	**-656**	**-564**	35	**1,913**	-227
Critically Dry (16%)	**398**	**798**	**448**	**394**	**-505**	-131	-148	**-1,465**	**-758**	**-554**	139	**-264**
Full Simulation Period Average	77	-70	**536**	376	208	45	**-337**	**482**	**-1,012**	**-757**	450	-312

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-249. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NO ACTION ALTERNATIVE												
Wet (28%)	8,228	8,683	13,701	29,751	36,916	25,296	15,001	9,396	9,243	12,998	9,757	9,264
Above Normal (14%)	7,428	9,038	10,730	19,185	26,409	17,672	9,071	9,166	10,002	14,637	10,364	8,607
Below Normal (18%)	6,469	6,914	13,860	10,404	10,259	9,322	7,698	10,248	10,293	13,473	10,270	5,856
Dry (24%)	5,710	6,807	13,495	6,375	10,498	8,387	7,311	8,682	10,748	12,483	8,649	5,677
Critically Dry (16%)	4,793	5,342	6,988	5,988	7,268	5,869	4,836	7,539	9,555	10,051	7,595	5,321
Full Simulation Period Average	6,672	7,466	12,227	15,377	19,563	14,187	9,384	9,049	9,949	12,718	9,322	7,067
ALTERNATIVE 3												
Wet (28%)	8,040	8,201	13,895	30,580	37,391	25,457	15,277	11,893	7,948	12,412	9,310	8,687
Above Normal (14%)	7,491	8,183	12,042	19,687	26,387	18,015	9,411	11,250	8,233	12,378	10,061	7,802
Below Normal (18%)	6,413	7,287	14,702	10,593	10,891	9,425	7,098	10,049	9,434	12,384	10,967	6,118
Dry (24%)	5,886	6,839	13,965	6,593	10,594	8,486	6,501	8,280	10,279	12,630	10,635	5,495
Critically Dry (16%)	5,247	6,141	7,428	6,454	6,806	5,772	4,856	6,394	8,954	9,639	7,829	5,090
Full Simulation Period Average	6,729	7,398	12,809	15,840	19,755	14,307	9,210	9,724	8,976	12,011	9,795	6,759
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-188	**-482**	195	830	475	161	276	**2,498**	**-1,296**	-586	-447	**-578**
Above Normal (14%)	63	**-855**	**1,312**	502	-23	343	340	**2,084**	**-1,769**	**-2,259**	-302	**-805**
Below Normal (18%)	-56	**373**	**842**	189	**632**	103	**-600**	-198	**-858**	**-1,089**	**697**	262
Dry (24%)	176	33	470	217	96	99	**-810**	-402	-469	146	**1,986**	-182
Critically Dry (16%)	**455**	**799**	**440**	**466**	**-462**	-97	20	**-1,145**	**-601**	-412	234	-231
Full Simulation Period Average	57	-69	582	463	193	120	-174	**676**	**-974**	**-707**	**472**	-308

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-250. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	6,747	7,468	10,397	18,705	19,917	17,996	14,436	7,416	5,607	7,544	5,925	7,204
Above Normal (14%)	5,961	7,038	9,668	15,284	18,028	16,281	11,131	6,025	5,489	8,795	6,524	6,581
Below Normal (18%)	4,873	5,672	11,096	10,852	11,463	11,209	8,152	5,869	5,299	7,459	6,026	3,788
Dry (24%)	4,113	5,375	9,640	7,139	11,119	10,068	6,993	4,676	5,632	6,501	4,502	3,592
Critically Dry (16%)	2,894	3,464	6,820	6,285	8,177	7,026	3,957	3,317	4,791	4,776	3,949	3,168
Full Simulation Period Average	5,082	5,977	9,695	12,049	14,141	12,876	9,379	5,629	5,410	7,011	5,369	4,989
ALTERNATIVE 3												
Wet (28%)	6,511	6,912	10,384	18,849	19,972	18,080	14,600	9,983	4,462	6,842	5,535	6,559
Above Normal (14%)	5,957	5,940	10,209	15,474	18,050	16,455	11,385	8,240	3,956	6,514	6,294	5,642
Below Normal (18%)	4,740	5,770	11,302	10,969	11,732	11,266	7,706	5,620	4,567	6,312	6,665	3,934
Dry (24%)	4,229	5,307	9,834	7,285	11,127	10,023	6,487	4,274	5,193	6,575	6,432	3,394
Critically Dry (16%)	3,378	4,003	7,051	6,702	7,801	6,871	4,406	3,286	5,326	5,470	4,918	3,250
Full Simulation Period Average	5,091	5,739	9,891	12,239	14,150	12,899	9,331	6,512	4,724	6,417	5,961	4,669
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-236	**-556**	-13	144	55	84	163	**2,567**	**-1,146**	**-702**	**-390**	**-645**
Above Normal (14%)	-4	**-1,098**	**540**	190	22	173	254	**2,215**	**-1,533**	**-2,281**	-229	**-939**
Below Normal (18%)	-134	97	206	117	270	57	**-446**	-250	**-732**	**-1,148**	**639**	147
Dry (24%)	116	-68	195	147	8	-45	**-506**	**-402**	**-439**	74	**1,930**	**-198**
Critically Dry (16%)	**484**	**539**	230	**416**	-376	-155	**449**	-31	**535**	**694**	**969**	82
Full Simulation Period Average	10	-238	196	190	9	22	-49	**883**	**-687**	**-594**	**592**	**-320**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-251. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,774	9,060	15,844	36,160	43,468	29,725	17,650	8,737	7,593	10,522	8,015	8,486
Above Normal (14%)	7,022	9,205	13,122	23,971	31,918	21,265	10,557	7,853	7,987	12,017	8,577	7,776
Below Normal (18%)	6,086	7,165	17,022	13,255	12,647	11,442	8,573	8,564	8,090	10,753	8,376	5,047
Dry (24%)	5,424	6,996	15,816	7,835	13,272	10,306	7,768	6,767	8,428	9,720	6,726	4,808
Critically Dry (16%)	4,248	5,011	8,610	7,004	8,624	6,911	4,760	5,640	7,496	7,846	6,133	4,536
Full Simulation Period Average	6,264	7,638	14,556	18,868	23,481	16,939	10,589	7,614	7,923	10,152	7,548	6,253
ALTERNATIVE 3												
Wet (28%)	7,581	8,574	16,067	36,975	43,932	29,879	17,915	11,237	6,314	9,929	7,574	7,906
Above Normal (14%)	7,076	8,345	14,468	24,463	31,890	21,597	10,910	9,955	6,248	9,764	8,284	6,963
Below Normal (18%)	6,019	7,528	17,884	13,438	13,272	11,541	8,041	8,370	7,246	9,664	9,068	5,299
Dry (24%)	5,591	7,021	16,324	8,045	13,359	10,397	7,098	6,369	7,962	9,864	8,709	4,623
Critically Dry (16%)	4,775	5,725	9,060	7,466	8,165	6,812	5,069	5,220	7,624	8,182	6,897	4,537
Full Simulation Period Average	6,326	7,551	15,165	19,322	23,667	17,052	10,505	8,410	7,078	9,563	8,106	5,978
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-193	**-486**	223	814	464	154	265	**2,499**	**-1,279**	**-593**	**-442**	**-580**
Above Normal (14%)	54	**-860**	**1,346**	492	-29	332	353	**2,101**	**-1,739**	**-2,254**	-294	**-813**
Below Normal (18%)	-67	**363**	**862**	183	624	99	**-532**	-194	**-844**	**-1,089**	**692**	252
Dry (24%)	168	26	508	209	87	91	**-670**	**-398**	**-466**	145	**1,983**	-185
Critically Dry (16%)	**527**	**714**	**450**	**462**	**-458**	-99	**309**	**-420**	128	335	**764**	1
Full Simulation Period Average	61	-87	609	454	186	113	-84	**796**	**-845**	**-589**	**558**	-275

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.6.3 Bay-Delta

Alternative 3 assumes a single unit operation is feasible for exports to meet public health and safety and would be shared between the CVP and SWP. From whichever is earlier, either January 1 or the onset of OMR management, until the earlier of June 30 or the offramp of OMR Management, flows shall not exceed -5,000 cfs on a 14-day running average. These requirements do not apply when San Joaquin River flows at Vernalis are greater than 20,000 cfs. In addition, when the SVI has been classified as a critically dry year for a second (or more) consecutive year, OMR flows shall not exceed -2,500 cfs on a 14-day running average. From April 1 to May 31, Reclamation and DWR would operate to achieve a 2:1 ratio of San Joaquin River inflow at Vernalis to combined CVP/SWP exports in all water year types. In addition to the requirements under D-1641, Reclamation and DWR would operate to meet the Delta Outflow criteria in Chapter 3 Alternatives Table 3.5 1 for the months of July to November. From December through June, Reclamation and DWR would operate to meet Delta Outflow that is the lesser of 65 percent of unimpaired Delta inflow or the Delta Outflow criteria in Chapter 3 Alternatives Table 3.5 1. Reclamation and DWR may release stored water to meet Delta outflow criteria in May through November. Reclamation and DWR may release stored water to meet Delta outflow criteria in May through November. Reclamation and DWR would prioritize meeting the storage requirements described in Chapter 3 Alternatives 3.5.5 Delta before making additional reservoir releases beyond what is required to meet D-1641 and human health and safety. In the summer and fall, Alternative 3 is the same as Alternative 2, except releases from upstream reservoirs are constrained to a Delta outflow of 7,100 cfs in November of wet and above normal years. Fall salinity may vary based on the ability of export reductions to achieve Fall X2 subject to public health and safety.

O.6.3.1 Delta X2

CalSim 3 modeling suggests that the estimated X2 position under Alternative 3 when compared to the No Action Alternative is further seaward in December and May for wet years, November–January in above normal years, in January in below normal years, in January and August–September for dry years and in December for critically dry years. (Table O-252). Table O-252 suggests that most landward X2 positions are expected during late summer to fall months in the critically dry years and the most seaward positions are expected during the winter to early spring months in wet years for both alternatives. For the full simulation period, when comparing Alternative 3 to the No Action Alternative, X2 was more seaward in December.

O.6.3.2 Delta Exports

CalSim 3 modeling suggests that the total exports of the SWP and CVP under Alternative 3 when compared to the No Action Alternative generally decrease across all water year types and months. Exports only increased in October for the dry water year type and August for the critical water year type. (Table O-253). Table O-253 suggests that exports were generally highest in February in above normal water year types for Alternative 3 and highest in July–August and November in the wet water year type for the No Action Alternative. Exports were generally the lowest in April-May during the critically dry water year type for Alternative 3 and in July–August during the critically dry water year type for the No Action Alternative. For the full simulation period, total exports when compared to the No Action Alternative decreased across all months.

O.6.3.3 Delta Outflow

Under Alternative 3 when compared to the No Action Alternative, total Delta outflow generally increases across most months and water year types. Outflow decreases in June and July of wet, above normal and below normal water year types and in September of wet, above normal and critically dry water year types and in October of the dry water year type (Table O-254). Table O-254 suggests total Delta outflow is highest in February during wet years and lowest in the late summer–fall during the critically dry water year type for both alternatives. For the full simulation period when compared to the No Action Alternative, total Delta outflow increased from November to May and August.

O.6.3.4 Delta OMR

CalSim 3 modeling suggests that Old and Middle River (OMR) combined flows under Alternative 3 when compared to the No Action Alternative is generally less negative across all water year types and months except for October in dry years and August in critically dry years (Table O-255). Table O-255 suggests that OMR flows were generally the most negative in November of below normal years for Alternative 3 and August of above normal years for the No Action Alternative, and the least negative in May during wet water years for both alternatives. For the full simulation period, OMR flows were less negative across all months.

O.6.3.5 Sacramento River at Rio Vista

CalSim 3 modeling suggests that average flows in the Sacramento River at Rio Vista under Alternative 3 compared to the No Action Alternative are similar or increased from November through May and similar or decreased June through October (Table O-256). The greatest reductions are expected during July of an above normal water year type under Alternative 3 compared to the No Action Alternative. The greatest increase is expected during April of critically dry water year types under Alternative 3 compared to the No Action Alternative.

Table O-252. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 3 and Differences between Them

Alternative	X2 Position (km)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	79	80	74	56	54	55	58	63	72	78	83	79
Above Normal (14%)	80	83	77	62	57	57	62	69	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	68	72	80	83	87	90
Dry (24%)	91	88	78	79	69	68	72	77	82	86	89	92
Critically Dry (16%)	94	93	85	82	77	77	83	87	89	92	93	93
Full Simulation Period Average	86	86	77	69	64	64	68	73	79	83	87	86
ALTERNATIVE 3												
Wet (28%)	79	77	69	55	53	55	57	59	72	78	81	79
Above Normal (14%)	80	79	70	59	56	56	60	64	76	82	83	80
Below Normal (18%)	87	87	71	66	63	62	64	70	79	84	85	86
Dry (24%)	89	87	76	73	66	66	69	74	80	83	84	87
Critically Dry (16%)	94	92	79	79	74	74	79	83	86	89	91	92
Full Simulation Period Average	85	84	73	66	62	62	65	69	78	83	84	84
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	-4	**-5**	-1	0	-1	-1	**-3**	0	0	-2	0
Above Normal (14%)	0	**-5**	**-7**	**-3**	-1	-1	-2	**-5**	0	2	0	0
Below Normal (18%)	-3	-2	-2	**-4**	-3	-3	-3	-2	0	1	-2	-4
Dry (24%)	-2	-1	-2	**-6**	-3	-2	-3	-3	-2	-2	**-5**	**-5**
Critically Dry (16%)	0	0	**-6**	-3	-3	-3	-4	-3	-3	-4	-3	-1
Full Simulation Period Average	-1	-2	**-4**	-3	-2	-2	-3	-3	-1	-1	-3	-2

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-253. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,586	10,782	8,504	9,217	9,986	8,557	7,132	6,750	7,386	10,597	10,891	8,364
Above Normal (14%)	5,987	10,099	8,039	7,441	8,282	6,935	4,259	4,336	5,864	10,356	10,686	5,703
Below Normal (18%)	5,887	7,526	7,027	6,408	7,112	6,214	3,808	3,669	5,502	9,913	8,767	6,714
Dry (24%)	4,225	6,067	5,475	6,216	6,321	5,760	3,082	2,916	4,929	7,138	4,116	5,320
Critically Dry (16%)	2,715	2,579	5,724	5,078	5,559	4,421	2,045	2,124	1,895	1,631	1,637	2,660
Full Simulation Period Average	5,503	7,732	7,024	7,080	7,642	6,575	4,345	4,197	5,365	8,175	7,373	6,051
ALTERNATIVE 3												
Wet (28%)	5,615	6,142	5,147	7,612	6,831	4,318	1,970	1,419	5,577	3,455	3,593	5,330
Above Normal (14%)	4,337	4,416	3,699	5,651	7,588	5,349	1,714	1,252	2,731	2,145	2,927	3,857
Below Normal (18%)	5,069	7,448	3,516	4,386	5,072	4,830	2,030	1,564	2,278	2,456	3,352	5,617
Dry (24%)	4,705	5,505	3,640	3,397	5,174	4,864	1,199	1,153	1,240	3,105	3,230	4,857
Critically Dry (16%)	2,615	2,256	1,527	3,963	4,350	2,722	1,017	966	1,163	1,633	2,027	2,577
Full Simulation Period Average	4,657	5,383	3,731	5,161	5,826	4,430	1,608	1,285	2,838	2,716	3,119	4,621
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**-1,972**	**-4,640**	**-3,358**	**-1,605**	**-3,154**	**-4,240**	**-5,162**	**-5,331**	**-1,809**	**-7,142**	**-7,298**	**-3,034**
Above Normal (14%)	**-1,650**	**-5,683**	**-4,340**	**-1,790**	**-693**	**-1,586**	**-2,544**	**-3,084**	**-3,133**	**-8,211**	**-7,759**	**-1,846**
Below Normal (18%)	**-818**	-78	**-3,511**	**-2,023**	**-2,040**	**-1,384**	**-1,778**	**-2,105**	**-3,224**	**-7,457**	**-5,415**	**-1,098**
Dry (24%)	**481**	**-562**	**-1,835**	**-2,818**	**-1,147**	**-896**	**-1,882**	**-1,763**	**-3,688**	**-4,033**	**-885**	**-463**
Critically Dry (16%)	-100	**-323**	**-4,196**	**-1,115**	**-1,209**	**-1,699**	**-1,028**	**-1,158**	**-732**	3	**390**	-84
Full Simulation Period Average	**-846**	**-2,349**	**-3,293**	**-1,919**	**-1,816**	**-2,145**	**-2,738**	**-2,912**	**-2,528**	**-5,459**	**-4,254**	**-1,430**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-254. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,918	12,055	30,736	96,898	122,709	90,897	54,587	31,188	13,556	9,410	6,009	11,294
Above Normal (14%)	8,664	7,873	21,249	53,164	71,004	58,493	27,859	17,453	9,163	10,682	6,287	10,956
Below Normal (18%)	5,366	6,747	30,789	25,764	29,373	26,423	19,249	15,376	7,772	8,121	4,144	3,679
Dry (24%)	5,887	9,013	30,407	13,571	27,568	19,839	14,134	10,846	7,191	5,232	3,826	3,213
Critically Dry (16%)	3,094	5,758	11,444	10,903	15,095	10,560	6,745	5,961	4,141	3,217	3,030	3,554
Full Simulation Period Average	6,640	8,798	26,350	44,213	58,618	44,847	27,121	17,500	8,866	7,363	4,712	6,698
ALTERNATIVE 3												
Wet (28%)	9,964	16,009	36,075	101,935	127,640	95,638	61,128	42,033	11,884	10,444	7,429	10,543
Above Normal (14%)	9,072	13,201	28,337	57,520	74,546	62,622	33,552	25,550	7,047	8,533	7,734	10,056
Below Normal (18%)	5,487	6,839	38,213	28,831	34,211	31,185	24,287	17,600	7,121	7,100	6,900	5,006
Dry (24%)	5,344	9,636	34,506	17,045	29,859	22,379	17,594	12,608	8,071	6,500	6,900	4,021
Critically Dry (16%)	3,033	5,923	18,038	12,510	15,857	12,792	8,947	7,192	5,938	4,500	4,000	3,224
Full Simulation Period Average	6,876	10,895	32,217	47,877	62,037	48,577	31,839	22,691	8,483	7,677	6,701	6,742
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**1,046**	**3,953**	**5,340**	**5,038**	4,931	**4,740**	**6,541**	**10,845**	**-1,671**	**1,034**	**1,419**	**-751**
Above Normal (14%)	408	**5,328**	**7,088**	**4,356**	3,541	**4,129**	**5,692**	**8,098**	**-2,116**	**-2,149**	**1,447**	**-900**
Below Normal (18%)	121	93	**7,424**	**3,067**	**4,838**	**4,762**	**5,039**	**2,224**	**-650**	**-1,021**	**2,756**	**1,327**
Dry (24%)	**-542**	**623**	**4,100**	**3,474**	**2,291**	**2,541**	**3,460**	**1,762**	**880**	**1,268**	**3,074**	**808**
Critically Dry (16%)	-61	166	**6,594**	**1,607**	**762**	**2,232**	**2,202**	**1,231**	**1,796**	**1,283**	**970**	**-330**
Full Simulation Period Average	236	**2,097**	**5,868**	**3,663**	**3,419**	**3,729**	**4,718**	**5,190**	-383	315	**1,989**	44

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-255. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	-6,128	-8,400	-5,569	-2,718	-1,706	-1,261	-1,861	-1,095	-4,159	-9,708	-10,116	-7,642
Above Normal (14%)	-4,935	-8,399	-5,963	-4,302	-3,528	-3,169	-1,650	-2,348	-4,778	-10,023	-10,386	-5,854
Below Normal (18%)	-5,152	-6,123	-4,900	-4,312	-4,100	-3,658	-2,060	-2,114	-4,859	-9,847	-9,043	-6,759
Dry (24%)	-3,644	-4,859	-3,704	-4,442	-4,031	-3,933	-2,095	-2,204	-4,796	-8,003	-4,819	-5,490
Critically Dry (16%)	-2,539	-1,982	-4,330	-3,630	-3,692	-3,053	-1,079	-1,748	-2,272	-2,668	-2,463	-3,002
Full Simulation Period Average	-4,639	-6,178	-4,875	-3,786	-3,268	-2,888	-1,798	-1,825	-4,222	-8,241	-7,465	-5,974
ALTERNATIVE 3												
Wet (28%)	-4,399	-4,239	-2,560	-1,377	1,356	2,805	3,249	3,903	-2,420	-3,101	-3,445	-4,853
Above Normal (14%)	-3,478	-3,267	-2,064	-2,816	-2,828	-1,562	714	643	-2,008	-2,487	-3,286	-3,927
Below Normal (18%)	-4,436	-6,066	-1,812	-2,512	-2,268	-2,315	-109	-160	-1,938	-2,959	-3,772	-5,518
Dry (24%)	-4,110	-4,374	-2,131	-1,923	-2,973	-3,083	-169	-519	-1,419	-3,788	-3,816	-4,912
Critically Dry (16%)	-2,437	-1,661	-541	-2,664	-2,644	-1,560	-189	-725	-1,642	-2,563	-2,759	-2,897
Full Simulation Period Average	-3,904	-4,068	-1,945	-2,120	-1,561	-840	919	913	-1,911	-3,068	-3,461	-4,544
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**1,728**	**4,162**	**3,009**	**1,341**	**3,062**	**4,065**	**5,109**	**4,998**	**1,738**	**6,606**	**6,671**	**2,789**
Above Normal (14%)	**1,457**	**5,132**	**3,899**	**1,485**	**701**	**1,607**	**2,364**	**2,991**	**2,770**	**7,536**	**7,100**	**1,927**
Below Normal (18%)	**716**	58	**3,087**	**1,800**	**1,831**	**1,343**	**1,951**	**1,954**	**2,921**	**6,888**	**5,271**	**1,240**
Dry (24%)	**-467**	**485**	**1,573**	**2,520**	**1,058**	**850**	**1,926**	**1,686**	**3,377**	**4,215**	**1,003**	**578**
Critically Dry (16%)	102	**321**	**3,790**	**965**	**1,048**	**1,493**	**890**	**1,023**	**630**	105	**-296**	105
Full Simulation Period Average	**735**	**2,110**	**2,929**	**1,667**	**1,707**	**2,048**	**2,717**	**2,738**	**2,312**	**5,173**	**4,004**	**1,429**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-256. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River at Rio Vista flow for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,929	13,097	29,134	82,363	104,439	73,383	40,479	20,772	9,466	11,109	9,638	11,382
Above Normal (14%)	7,795	10,558	22,225	47,116	62,080	48,912	20,595	13,844	7,846	13,276	10,441	10,213
Below Normal (18%)	6,147	8,224	29,745	23,742	25,296	22,329	14,058	12,234	7,154	11,407	8,272	6,178
Dry (24%)	6,377	9,250	27,844	13,212	25,067	17,799	11,076	9,263	7,324	8,513	5,224	5,046
Critically Dry (16%)	3,621	4,344	12,645	10,561	13,992	9,893	4,748	5,310	3,824	3,870	3,391	3,869
Full Simulation Period Average	6,849	9,603	25,425	38,792	50,742	37,269	20,166	13,029	7,406	9,685	7,446	7,559
ALTERNATIVE 3												
Wet (28%)	8,560	12,903	31,113	85,835	105,899	73,627	42,050	25,485	6,852	7,327	5,895	8,977
Above Normal (14%)	7,359	10,687	24,903	49,785	64,545	50,972	23,744	17,978	4,302	6,174	6,344	8,306
Below Normal (18%)	6,327	8,466	33,555	24,730	27,853	25,177	16,874	12,308	4,560	5,828	6,378	6,227
Dry (24%)	6,497	9,584	30,141	13,869	26,043	19,254	12,432	9,194	5,413	6,415	6,607	5,217
Critically Dry (16%)	3,632	4,263	14,747	11,049	13,690	10,487	5,905	5,444	4,571	4,692	4,328	3,626
Full Simulation Period Average	6,744	9,679	27,933	40,551	52,142	38,582	22,064	14,946	5,372	6,255	5,965	6,630
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-368	-194	**1,979**	3,471	1,460	244	1,571	**4,713**	**-2,614**	**-3,781**	**-3,743**	**-2,405**
Above Normal (14%)	**-436**	129	**2,678**	**2,669**	2,465	2,061	**3,149**	**4,135**	**-3,544**	**-7,102**	**-4,097**	**-1,906**
Below Normal (18%)	180	241	**3,810**	988	**2,557**	**2,849**	**2,817**	74	**-2,595**	**-5,579**	**-1,894**	49
Dry (24%)	120	334	**2,297**	657	976	**1,455**	**1,356**	-69	**-1,912**	**-2,098**	**1,383**	171
Critically Dry (16%)	11	-81	**2,102**	488	-302	**593**	**1,157**	134	**748**	**822**	**937**	**-243**
Full Simulation Period Average	-106	77	**2,508**	1,759	1,400	1,314	**1,898**	**1,916**	**-2,034**	**-3,429**	**-1,481**	**-929**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.6.4 Clear Creek

Under Alternative 3, Reclamation would release water through Whiskeytown Dam to provide intra-annual variation to emulate natural processes. As provided in Figure 3.4-1 and Table 3.4-2 (EIS, Chapter 3), flows would oscillate over a one-year period, with releases transitioning from 300 cfs in the winter, down to 100 cfs in the summer, and back to 300 cfs by the following winter. Reclamation, through the Clear Creek Technical Team, may modify the timing and flow rates provided in Figure 3.4-1 and Table 3.4-2 by February 1 and update through May on a case-by-case basis; the flow schedule is subject to agreement by Redding Electric Utility for use of their facilities.

Reclamation would release up to 10,000 acre-feet from Whiskeytown Dam for channel maintenance, spring attraction flows, and to meet other physical and biological objectives, except in years with significant uncontrolled flow. In critical years, Reclamation would release up to 5,000 acre-feet. Reclamation, through the Clear Creek Technical Team, would develop pulse flow schedules, which include measures (e.g., nighttime down ramping, slow down ramping rates, coordination with natural precipitation events) to mitigate for potential risks (e.g., potential juvenile fish stranding). Due to unknowns in winter precipitation, Clear Creek pulse flows are not to occur prior to the February SVI reporting. The full pulse flow volume (10,000 acre-feet) will be available if the SVI is greater than 5.4, at the SVI updates (i.e., dry or wetter years). If the SVI updates are equal to or less than 5.4 (critical years), Reclamation would limit releases of pulse(s) flows to 5,000 acre-feet. Reclamation would also target Whiskeytown Dam releases at except that Reclamation will manage Whiskeytown Dam releases to not exceed mean daily water temperatures of 60°F at the Igo gauge from June 1 through September 15 and 56°F from September 15 through November 15. In dry, critical, or import curtailment years, Reclamation may not be able to meet these water temperatures and will operate Whiskeytown Dam as close to these water temperatures as practicable within the constraints of minimum instream flows.

O.6.4.1 Clear Creek below Whiskeytown Dam

CalSim 3 modeling suggests that monthly average flows below Whiskeytown Dam under Alternative 3 compared to the No Action Alternative are expected to increase November through January and March through May, and decrease February and June through October (Table O-257). The largest increases under Alternative 3 compared to the No Action Alternative are expected March through May. The largest decreases under Alternative 3 compared to the No Action Alternative are expected in June through August.

Table O-257. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	200	200	200	305	494	300	200	200	318	150	150	150
Above Normal (14%)	200	200	200	193	365	200	200	200	318	150	150	150
Below Normal (18%)	200	190	192	194	339	200	200	200	318	150	150	142
Dry (24%)	200	200	200	194	232	192	196	200	318	150	150	150
Critically Dry (16%)	117	100	143	177	169	166	153	150	225	145	141	137
Full Simulation Period Average	187	183	190	222	333	221	192	192	303	149	149	146
ALTERNATIVE 3												
Wet (28%)	157	210	260	387	427	383	247	278	232	113	100	120
Above Normal (14%)	157	210	260	272	300	286	247	278	232	113	100	120
Below Normal (18%)	157	210	260	277	300	286	247	278	232	113	100	120
Dry (24%)	157	210	260	275	263	264	239	278	232	113	100	120
Critically Dry (16%)	140	130	141	229	211	193	156	231	140	106	94	110
Full Simulation Period Average	155	198	242	299	312	293	230	271	217	112	99	118
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**-43**	10	**60**	**83**	**-67**	**83**	**47**	**78**	**-87**	**-37**	**-50**	**-30**
Above Normal (14%)	**-43**	10	**60**	**79**	**-65**	**86**	**47**	**78**	**-87**	**-37**	**-50**	**-30**
Below Normal (18%)	**-43**	**20**	**67**	**82**	**-39**	**86**	**47**	**78**	**-87**	**-37**	**-50**	**-22**
Dry (24%)	**-43**	10	**60**	**81**	**31**	**72**	**43**	**78**	**-87**	**-37**	**-50**	**-30**
Critically Dry (16%)	**23**	**31**	-2	**52**	**42**	**27**	3	**81**	**-85**	**-39**	**-47**	**-28**
Full Simulation Period Average	**-33**	**15**	**52**	**77**	**-21**	**72**	**39**	**79**	**-86**	**-37**	**-50**	**-28**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.6.5 Lower American River

Under Alternative 3, management actions for the lower American River would be the same as the No Action Alternative Reclamation and would implement the minimum release requirement (MRR) proposed by the Sacramento Area Water Forum, based on the month and annual hydrology, Figure 3.2-3 and Figure 3.2-4 (EIS, Chapter 3), except it would implement End of September 300 TAF (230 TAF in a second consecutive dry or critical water year type) and End of December 300 TAF as necessary to achieve storage targets. Reclamation will use the 90% exceedance from the Sacramento River Index in January and the lower American River Index in February through December to develop the MRR (with certain spills subtracted). Subject to annual modeling demonstrating that operations are reasonably likely to meet the storage requirements described above, Alternative 3 bypasses 55% of unimpaired inflows to Folsom Reservoir from December through May to achieve the monthly Delta Outflow criteria in Table 3.5-1 (EIS, Chapter 3). Subject to achieving the storage requirements described above, Reclamation may release stored water from May to November to meet the Delta Outflow criteria described in Table 3.5-1 (EIS, Chapter 3). If the monthly Delta Outflow criteria is met, then releases from Folsom Reservoir that month may be reduced to 45% of unimpaired inflows from December through May.

O.6.5.1 Lower American River for Folsom Reservoir Storage

CalSim 3 modeling suggests that monthly average volume of Folsom Storage under Alternative 3 compared to the No Action Alternative is generally expected to be similar, except in April and May when storage is expected to be lower (Table O-258). The largest increases are expected July through November in above normal and below normal water year types. The largest decreases are expected April and May (up to 10%) of above normal and below normal water year types.

O.6.5.2 Lower American River below Nimbus Dam

CalSim 3 modeling suggests that monthly average flows under Alternative 3 compared to the No Action Alternative are similar (less than a 5% difference) September through February, and are expected to increase or decrease depending on the month March through August (Table O-259). Under Alternative 3 compared to the No Action Alternative, the largest increases in flow were in April and decreases would are expected in June of almost all water year types except wet and critically dry water year types. Wet water year types could generally be similar most months except June and September would be lower under Alternative 3 compared to the No Action Alternative; in critically water year types, the largest increases in flow are expected in December (up to 62%) and decreases would be expected in November (up to 29%).

O.6.5.3 Lower American River at H Street

CalSim 3 modeling suggests monthly average flows in the lower American River at H street under Alternative 3 compared to the No Action Alternative are similar (less than a 5% difference) September through February, and are expected to increase or decrease depending on the month March through August (Table O-260). Under Alternative 3 compared to the No Action Alternative, the largest increases in flow were in April and decreases would are expected in June of almost all water year types except wet and critically dry water year types. Wet water year types could generally be similar most months except June and September would be lower under Alternative 3 compared to the No Action Alternative; in critically water year types, the largest increases in flow are expected in December and decreases are expected in November.

Table O-258. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	621	533	532	567	567	750	890	947	923	781	693	654
Above Normal (14%)	484	447	502	557	565	745	879	932	858	633	570	518
Below Normal (18%)	454	433	485	540	560	711	836	846	790	576	502	476
Dry (24%)	436	439	470	472	518	633	716	725	657	532	471	447
Critically Dry (16%)	341	318	430	430	452	503	529	524	500	440	376	362
Full Simulation Period Average	484	447	489	516	535	675	779	806	758	609	537	507
ALTERNATIVE 3												
Wet (28%)	630	539	536	567	566	743	869	925	928	784	693	664
Above Normal (14%)	520	472	518	561	566	727	807	849	859	697	599	554
Below Normal (18%)	501	483	511	546	563	678	749	770	782	652	553	520
Dry (24%)	449	447	479	490	524	633	677	698	682	568	478	455
Critically Dry (16%)	343	343	421	436	460	496	503	498	487	428	377	364
Full Simulation Period Average	504	467	498	523	539	663	734	763	763	639	553	524
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	9	6	4	0	-1	-7	-21	-22	5	3	0	10
Above Normal (14%)	**35**	**25**	17	3	1	-18	**-72**	**-83**	1	**64**	**29**	**36**
Below Normal (18%)	**47**	**49**	**26**	6	2	-33	**-87**	**-76**	-8	**76**	**51**	**44**
Dry (24%)	13	8	9	19	7	0	**-39**	-28	26	**36**	8	8
Critically Dry (16%)	2	**25**	-9	6	8	-7	-26	**-26**	-13	-12	1	2
Full Simulation Period Average	20	20	9	7	3	-11	**-45**	**-42**	4	30	15	18

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-259. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Lower American River below Nimbus Dam for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,870	4,067	4,854	11,628	12,283	7,659	6,803	6,359	3,663	3,631	2,804	2,514
Above Normal (14%)	1,893	2,418	3,339	6,518	7,463	4,965	3,295	3,324	3,311	4,618	2,260	2,283
Below Normal (18%)	1,578	2,012	4,112	2,926	4,355	2,781	2,822	2,947	2,778	4,557	2,449	1,750
Dry (24%)	1,227	2,276	5,167	1,667	3,197	2,077	2,172	2,492	2,598	2,910	1,968	1,529
Critically Dry (16%)	761	1,347	911	1,368	1,759	1,149	970	1,302	1,425	1,613	1,689	1,016
Full Simulation Period Average	1,500	2,612	3,977	5,314	6,317	4,022	3,551	3,583	2,841	3,440	2,285	1,868
ALTERNATIVE 3												
Wet (28%)	1,882	4,119	4,884	11,686	12,311	7,762	7,044	6,375	3,216	3,657	2,855	2,344
Above Normal (14%)	1,867	2,585	3,483	6,561	7,526	5,268	4,210	3,506	1,913	3,604	2,808	2,162
Below Normal (18%)	1,501	1,999	4,498	2,904	4,439	3,367	3,736	2,767	1,663	3,203	2,843	1,881
Dry (24%)	1,149	2,356	5,157	1,810	3,421	2,199	2,831	2,316	1,713	2,760	2,426	1,542
Critically Dry (16%)	719	956	1,474	1,292	1,735	1,388	1,288	1,318	1,210	1,615	1,479	1,019
Full Simulation Period Average	1,461	2,610	4,158	5,354	6,398	4,267	4,120	3,541	2,072	3,026	2,523	1,830
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	12	52	30	58	28	103	240	16	**-448**	25	51	**-170**
Above Normal (14%)	-25	**167**	144	43	64	**303**	**915**	**182**	**-1,398**	**-1,014**	**549**	**-121**
Below Normal (18%)	-77	-13	**386**	-23	84	**586**	**914**	**-180**	**-1,115**	**-1,354**	**393**	**131**
Dry (24%)	**-78**	80	-10	**143**	**224**	**122**	**659**	**-176**	**-885**	**-149**	**458**	12
Critically Dry (16%)	**-42**	**-392**	**564**	**-76**	-25	**239**	**319**	16	**-215**	2	**-210**	3
Full Simulation Period Average	-39	-2	182	40	82	**244**	**569**	-42	**-769**	**-414**	**238**	-38

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-260. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Lower American River at H Street for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,769	4,000	4,824	11,646	12,307	7,643	6,758	6,245	3,516	3,454	2,635	2,367
Above Normal (14%)	1,783	2,340	3,332	6,539	7,493	4,921	3,216	3,200	3,141	4,416	2,082	2,131
Below Normal (18%)	1,467	1,936	4,092	2,902	4,314	2,732	2,736	2,811	2,598	4,344	2,260	1,613
Dry (24%)	1,131	2,200	5,124	1,625	3,176	2,012	2,077	2,351	2,416	2,705	1,777	1,388
Critically Dry (16%)	647	1,251	905	1,303	1,712	1,075	862	1,165	1,244	1,416	1,495	867
Full Simulation Period Average	1,395	2,535	3,953	5,297	6,307	3,976	3,471	3,453	2,671	3,243	2,102	1,723
ALTERNATIVE 3												
Wet (28%)	1,777	4,048	4,852	11,702	12,332	7,744	6,996	6,260	3,070	3,476	2,681	2,194
Above Normal (14%)	1,755	2,502	3,473	6,580	7,554	5,222	4,128	3,382	1,751	3,401	2,617	2,006
Below Normal (18%)	1,385	1,919	4,473	2,878	4,395	3,315	3,647	2,632	1,490	2,995	2,643	1,730
Dry (24%)	1,050	2,276	5,111	1,765	3,396	2,132	2,734	2,177	1,535	2,551	2,225	1,394
Critically Dry (16%)	603	862	1,466	1,225	1,684	1,310	1,179	1,179	1,030	1,420	1,285	867
Full Simulation Period Average	1,353	2,530	4,131	5,335	6,386	4,217	4,038	3,411	1,906	2,828	2,333	1,680
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	9	48	28	56	26	101	238	14	**-446**	23	46	**-173**
Above Normal (14%)	-28	**162**	141	41	61	**301**	**912**	**181**	**-1,391**	**-1,015**	**535**	**-125**
Below Normal (18%)	**-82**	-17	**381**	-24	81	**583**	**911**	**-179**	**-1,108**	**-1,349**	**383**	**117**
Dry (24%)	**-81**	76	-13	**139**	**220**	**119**	**657**	**-175**	**-881**	**-154**	**448**	6
Critically Dry (16%)	**-44**	**-389**	**561**	**-78**	-28	**236**	**316**	14	**-214**	4	**-210**	0
Full Simulation Period Average	-42	-5	179	38	79	**242**	**567**	-43	**-765**	**-415**	**231**	-43

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.6.6 Stanislaus River

Consistent with the 2018 Bay-Delta Water Quality Control Plan, this component is consistent with the No Action Alternative in the summer and fall and it requires New Melones Reservoir to meet 40% of unimpaired inflow on a 7-day running average to the confluence with the San Joaquin River in February through June; in these months, Reclamation also would make releases from New Melones Dam as necessary to contribute its share (29%) of meeting the 1,000 cfs minimum flow at Vernalis. Reclamation would reduce deliveries to all contractors to achieve a minimum end of September storage in New Melones of 700 TAF. Reclamation through Governance, would schedule fall pulse flow volumes consistent with the volumes in the SRP and potentially release additional flows in October and November.

O.6.6.1 Stanislaus River below Goodwin Dam

CalSim 3 modeling suggests monthly average flows under Alternative 3 compared to No Action Alternative below Goodwin Dam will increase February through June, and decrease August, September, December, and January (Table O-261). Under Alternative 3 compared to the No Action Alternative, the largest increases in flow are expected in February, March, or June and decreases are expected in June or December of almost all water year types. Under Alternative 3 compared to the No Action Alternative, critically water year types are projected to have similar flow conditions almost all months except June, when these would be higher.

O.6.6.2 Stanislaus River at Mouth

CalSim 3 modeling suggests monthly average flows under Alternative 3 compared to No Action Alternative at the mouth of the Stanislaus River will increase February through July and decrease August, September, December, and January (Table O-262). Under Alternative 3 compared to the No Action Alternative, the largest increases in flow are expected in March, April, or June and decreases are expected in January, August, or December of almost all water year types except critically dry water year types. Under Alternative 3 compared to the No Action Alternative, critically water year types are projected to have lower or similar flow conditions and may have the greatest flow decrease in July.

Table O-261. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	875	578	752	2,005	2,111	1,887	1,680	1,984	747	288	741	870
Above Normal (14%)	742	200	352	782	1,297	889	1,177	1,134	456	273	287	260
Below Normal (18%)	685	200	462	417	641	382	846	868	335	267	284	280
Dry (24%)	617	200	490	241	230	200	636	563	269	265	283	249
Critically Dry (16%)	591	200	200	217	219	200	529	453	262	268	283	249
All	716	306	494	838	978	802	1,025	1,078	440	273	412	430
ALTERNATIVE 3												
Wet (28%)	883	570	733	1,950	2,632	2,151	2,015	2,440	1,236	280	466	802
Above Normal (14%)	747	209	259	580	1,531	1,190	1,525	1,454	546	270	285	257
Below Normal (18%)	649	200	211	424	650	623	1,047	965	359	267	284	252
Dry (24%)	612	200	359	239	387	321	737	733	295	265	283	249
Critically Dry (16%)	591	200	200	217	217	199	529	452	278	270	283	249
All	712	305	398	796	1,196	990	1,228	1,309	603	271	335	405
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	9	-8	-19	-55	**521**	**264**	**335**	**457**	**489**	-7	**-275**	**-68**
Above Normal (14%)	5	9	**-93**	**-201**	**235**	**301**	**348**	**320**	**90**	-2	-1	-4
Below Normal (18%)	**-36**	0	**-252**	7	9	**241**	**201**	**96**	**24**	0	0	**-28**
Dry (24%)	-5	0	**-131**	-2	**156**	**121**	**101**	**170**	**26**	0	0	0
Critically Dry (16%)	0	0	0	0	-1	-1	0	0	**16**	2	0	0
All	-4	-1	**-96**	**-43**	**217**	**188**	**203**	**231**	**163**	-2	**-77**	**-25**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-262. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	844	777	777	1,818	2,241	2,015	1,903	2,079	1,047	549	653	771
Above Normal (14%)	559	413	411	778	1,290	1,052	1,205	1,243	643	377	313	274
Below Normal (18%)	530	396	468	450	676	519	870	984	513	312	293	291
Dry (24%)	474	354	470	330	395	276	601	707	362	235	257	258
Critically Dry (16%)	404	303	245	290	343	210	478	550	252	135	185	191
All	590	482	513	825	1,079	905	1,079	1,191	603	340	370	399
ALTERNATIVE 3												
Wet (28%)	806	756	756	1,682	2,665	2,490	2,408	2,712	1,694	647	541	679
Above Normal (14%)	545	402	338	601	1,565	1,511	1,742	1,687	840	409	314	259
Below Normal (18%)	490	362	295	457	707	785	1,238	1,218	585	316	285	269
Dry (24%)	451	333	354	310	509	418	802	900	407	236	241	237
Critically Dry (16%)	383	284	227	275	324	188	456	525	241	105	157	169
All	561	460	434	756	1,267	1,180	1,407	1,515	834	369	330	359
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-39	-21	-20	**-136**	**424**	**475**	**505**	**633**	**647**	**98**	**-112**	**-92**
Above Normal (14%)	-14	-12	**-74**	**-177**	**275**	**458**	**537**	**444**	**197**	**32**	0	**-14**
Below Normal (18%)	**-40**	**-35**	**-174**	7	31	**266**	**368**	**234**	**72**	5	-8	**-22**
Dry (24%)	-24	**-21**	**-116**	**-20**	**114**	**141**	**201**	**193**	**45**	1	**-15**	**-21**
Critically Dry (16%)	**-21**	**-19**	**-19**	**-15**	**-20**	**-21**	-22	-25	-11	**-30**	**-28**	**-22**
All	-29	-22	**-79**	**-69**	**187**	**276**	**328**	**324**	**231**	**28**	**-41**	**-40**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.6.7 San Joaquin River

Under Alternative 3, Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision, which is a related action not included in this consultation. There are anticipated changes in San Joaquin River flow below the confluence with the Stanislaus River, because of changes in operations at New Melones Reservoir.

O.6.7.1 San Joaquin River at Vernalis

CalSim 3 modeling suggests that monthly average flows in the San Joaquin River at Vernalis under Alternative 3 compared to No Action Alternative will increase slightly in May and February and decrease all other months (Table O-263). There are no anticipated increases greater than a 5% difference under Alternative 3 compared to the No Action Alternative. The largest decreases under Alternative 3 compared to the No Action Alternative are expected in April of all water year types.

Table O-263. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 3 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	2,982	2,957	4,091	9,879	13,068	12,499	12,532	11,481	7,391	3,577	2,375	2,263
Above Normal (14%)	2,222	1,876	2,549	4,210	7,063	6,332	6,587	4,709	3,201	1,899	1,412	1,367
Below Normal (18%)	1,830	1,720	2,722	2,738	4,312	4,104	4,914	3,862	2,439	1,486	1,183	1,215
Dry (24%)	1,542	1,514	2,585	1,992	2,732	2,550	2,992	2,406	1,486	963	925	1,019
Critically Dry (16%)	1,288	1,244	1,499	1,821	2,162	2,038	2,287	1,665	1,129	560	616	738
All	2,061	1,969	2,863	4,618	6,425	6,063	6,399	5,413	3,494	1,856	1,396	1,407
ALTERNATIVE 3												
Wet (28%)	2,799	2,828	3,967	9,610	13,336	12,558	10,509	11,356	7,196	2,803	2,017	1,989
Above Normal (14%)	2,088	1,781	2,400	3,925	7,222	6,436	5,255	4,808	3,015	1,483	1,172	1,168
Below Normal (18%)	1,698	1,595	2,461	2,647	4,257	4,086	4,119	3,911	2,303	1,219	1,002	1,090
Dry (24%)	1,430	1,408	2,380	1,896	2,772	2,455	2,510	2,507	1,422	803	756	878
Critically Dry (16%)	1,193	1,184	1,435	1,732	2,065	1,832	2,024	1,596	1,068	466	504	646
All	1,925	1,862	2,700	4,449	6,507	6,035	5,346	5,414	3,364	1,479	1,171	1,231
ALTERNATIVE 3 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	**-183**	-129	-124	-269	268	58	**-2,023**	-125	-195	**-774**	**-358**	**-274**
Above Normal (14%)	**-134**	**-96**	**-149**	**-286**	159	104	**-1,332**	99	**-186**	**-417**	**-240**	**-199**
Below Normal (18%)	**-132**	**-124**	**-261**	-92	-55	-18	**-795**	49	**-136**	**-266**	**-180**	**-125**
Dry (24%)	**-112**	**-107**	**-205**	-96	40	-95	**-482**	101	-65	**-160**	**-170**	**-141**
Critically Dry (16%)	**-95**	-60	-64	-90	-97	**-205**	**-263**	-68	**-60**	**-94**	**-112**	**-92**
All	**-136**	**-108**	**-163**	-169	82	-28	**-1,054**	1	-130	**-377**	**-225**	**-176**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.6.8 Sacramento River Winter-run Chinook Salmon ESU

O.6.8.1 Sacramento River

Spawning and Egg/Alevin Incubation

Winter-run Chinook salmon adults spawn from April through August with peak spawning between May and July (Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). Fry emergence occurs up to three months after eggs are spawned, so effects of flow and water temperature on winter-run eggs and alevins may occur from May through November, but primarily occur during June through October.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 3, differences in mean spawning WUA increases in above normal, below normal, and dry water year types, and decreases in wet and critically dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 3 and the No Action Alternative is a 5.6% increase in wet water years. The largest reduction in estimated spawning habitat is a -0.3% decrease in critically dry water year types.

The monthly median value of spawning WUA under Alternative 3 similar to the No Action Alternative in May, June, and August but is slightly higher in July. Spawning WUA median values for all the modeled alternatives are relatively similar in May, June, and August. In July, the median values of spawning WUA are lower across all alternatives when compared to the other months of spawning. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in July than in the other three months (Table O-248). This results in lower spawning WUA results because the winter-run spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 5,000 to 10,000 cfs).

The results of suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for winter-run Chinook salmon in the upper Sacramento River may not a limiting factor under both the No Action Alternative and Alternative 3 (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The results of the two spawning habitat analyses based on CalSim 3 simulated flows suggest that Alternative 3 may have a minor increase (5.6%) in estimated spawning habitat during above normal water year types when compared to the No Action Alternative, and that spawning habitat may not be a limiting factor for winter-run Chinook salmon in the mainstem upper Sacramento River.

SIT Winter-run Lifecycle Model: Spawner Abundance

In the CVPIA winter-run SIT life cycle model, mean winter-run Chinook salmon spawner abundance in the central valley under Alternative 3 is similar to the No Action Alternative, with up 3.6% increase in above normal water year types and 1.0% decrease in critically dry water year types (Attachment F.2, *CVPIA SIT Winter-run LCM*). For all years, the mean annual spawner

abundance was similar under Alternative 3 compared to the No Action Alternative. Over the full model run period (1980–1999), abundance growth under Alternative 3 was slightly higher by 0.8% than abundance under the No Action Alternative. Overall, the spawner abundance predicted by the CVPIA winter-run life cycle model is expected to be similar under Alternative 3 and the No Action Alternative, with a slight annual decrease in abundance, with abundance decreases during critically dry and above normal years and increases during above normal and wet years.

IOS: Egg Survival

Under Alternative 3, in critically dry water years, mean predicted winter-run Chinook salmon egg survival is 32.05% higher than when compared to the No Action Alternative. Alternative 3 reflects a change of 0.224 mean predicted winter-run Chinook salmon egg survival when compared to the No Action Alternative (0.698 under the No Action Alternative to 0.922 under Alternative 3). The change in mean predicted winter-run Chinook salmon egg survival in all other water year types less than or equal to ± 0.004. Alternative 3 provides a substantial benefit to predicted survival of winter-run Chinook salmon eggs during critically dry years when compared to the No Action Alternative.

OBAN: Spawner Abundance and Probability of Quasi-Extinction

Predicted spawner abundance under Alternative 3 was greater than under the No Action Alternative (1% greater median proportional difference, Table O-30). This increase under Alternative 3 would have a beneficial effect on winter-run Chinook salmon.

Probability of quasi-extinction under Alternative 3 was less than under the No Action Alternative (0.94, Table O-30). This decrease under Alternative 3 would have a beneficial effect on winter-run Chinook salmon.

IOS: Female Escapement

Under Alternative 3 VA in all water year types, mean annual predicted female escapement of winter-run Chinook salmon is 16.87-27.28% higher than when compared to the No Action Alternative. The change in mean annual predicted female escapement of in all water year types ranging from 359 to 1,000 individuals. Alternative 3 provides a substantial positive impact to mean annual predicted female escapement of winter-run Chinook salmon when compared to the No Action Alternative.

OBAN: Egg-to-Fry Survival

Egg to fry survival under Alternative 3 was less than under the No Action Alternative (-0.033 difference, Table O-30).

Redd Dewatering Analysis

Alternative 3 shows minor increases in winter-run Chinook salmon redd dewatering potential from wet to dry water years, and an intermediate level for critically dry years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). During winter and spring, the principal incubation periods for the other Chinook salmon races and steelhead, redd dewatering is generally higher during wet water years because periodic storms and high runoff, which increase flow fluctuations, tend to be more frequent in such water years. However, winter-run Chinook salmon spawning and incubation occur during late spring through early fall, when flows tend to

be less variable. The low percentages of winter-run Chinook salmon redd dewatering in wet years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*) may result from increased stability in project operations related to greater reservoir storage levels. For individual months, median redd dewatering is highest for spawning in July and August and lowest for spawning in May (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The largest difference between the No Action Alternative and Alternative 3 is a 14.4% increase for wet water years and the largest reduction is 11.9% for above normal water years. Note that these large percentages may be misleading as they represent, respectively, 1.0% and 1.4% absolute differences in percent of redds dewatered (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that redd dewatering potential under Alternative 3 would be generally similar to that under the No Action Alternative, with some notable increases and reductions depending on water year type. In terms of absolute change, all differences are small.

Temperature Dependent Mortality (TDM)

Differences in monthly temperatures on the upper Sacramento River under Alternative 3 compared with the No Action Alternative may have effects on water-temperature-related mortality of winter-run Chinook salmon eggs and alevins. These possible differences were evaluated using several quantitative temperature-dependent models (TDM), hereinafter referred to as the Martin and Anderson models.

Both Martin and Anderson models are responsive to modeled Sacramento River temperatures at Keswick Dam, at the confluence with Clear Creek, and at Bend Bridge. The modeling was based on HEC-5Q water temperature estimates for the years used in the HEC-5Q modeling (1922–2021).

Under Alternative 3 for the Anderson model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.065, 0.312, and 0.006 (56% less than the No Action Alternative in critically dry water year types; 75% greater than the No Acton Alternative in wet water year types). Expected proportional TDM values for the Anderson model were less under Alternative 3 than No Action Alternative for all water year types except wet.

Under Alternative 3 for the Martin model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.089, 0.389, and 0.011 (all less than the No Action Alternative, up to 44% less in a critically dry water year type). Expected proportional TDM values for the Martin model were less under Alternative 3 than No Action Alternative in all water year types (up to 82% less in a below normal water year type).

Relative to the Anderson model, expected proportional TDM values were higher for the Martin model across all water year types combined and for all water year types. For the Anderson and Martin models, greater than 70% of modeled water years resulted in expected proportional TDM values less than 0.125. For critically dry water year types, at least 12.5% of modeled water years resulted in expected proportional TDM values less than 0.5. For above normal and wet water year types only, expected proportional TDM never exceeded 0.125 (Attachment L.2, *Egg-to-fry Survival and Temperature Dependent Mortality*). A decrease in TDM under Alternative 3

compared with the No Action Alternative in all but a wet water year type would generally have a beneficial effect on incubating winter-run Chinook salmon eggs.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 16 for Keswick Dam and Table 18 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 20 for Keswick Dam and Table 22 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during May through November are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 24 for Keswick Dam and Table 26 for below Clear Creek.

Results for the three analyses are summarized in Table O-31. Table O-31, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 42.1°F to 55°F range for spawning initiation, there were eight to 11 month-water year type combinations (22.9% to 31.4%) with favorable results, depending on location, no combinations (0% of total combinations during the period) with unfavorable results at Keswick Dam, and one combination (2.9%) with unfavorable effects below Clear Creek (Table O-31). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four to six combinations (11.4% to 17.1%) with favorable results, depending on location, and one combination (2.9%) with unfavorable results at each location. These results suggest that there would be mostly no effect or positive biologically meaningful temperature-related effects of Alternative 3 on winter-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River, although there were some negligible negative effects on spawning initiation and egg incubation and fry emergence.

Summary

Alternative 3 relative to the No Action Alternative is expected to have possible beneficial to adverse impacts on spawning and redd dewatering habitat, possible beneficial or adverse impacts on spawner abundance depending on water year type, possible substantial beneficial impacts on female escapement, and possible beneficial impacts on the probability of quasi-extinction due to differences in flow. Alternative 3 relative to the No Action Alternative are expected to have possible beneficial impacts using three secondary biological models: IOS, and both Anderson and Martin (TDM). OBAN results suggest differences in temperature between Alternative 3 and the No Action Alternative are expected to have possible adverse impacts on egg to fry survival due to differences in water temperature. Using a coarser analysis, Alternative 3 relative to the No Action Alternative is expected to have a possible minor beneficial impact on spawning and egg/alevin incubation but minor adverse impacts on spawning initiation and egg incubation and fry emergence due to differences in water temperature.

Juvenile Rearing and Emigration

Winter-run Chinook salmon juveniles rear in the Sacramento River primarily from late summer to late winter and emigrate from the river to the Delta beginning in November (see Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). The proportion of juveniles surviving to emigrate to the Delta depends largely on habitat conditions, including flow and water temperature. Inundated floodplain habitat has been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001a, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 3, mean fry rearing WUA increases in all water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increases in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 2.1% increase in wet and critically dry water years. There are no anticipated reductions in mean fry rearing WUA in comparison to the No Action Alternative.

The monthly median value of fry rearing WUA under Alternative 3 is similar to the No Action Alternative throughout the fry rearing period (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Fry rearing WUA median values for all the modeled alternatives are relatively similar September through December but slightly lower in August. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in August in comparison to the other fry rearing months, with an average flow of 10,225 cfs under Alternative 3 (Table O-248). Segment 5, which has the highest distribution of winter-run Chinook salmon spawning, has decreased WUA values when flows are between 5,000 and 10,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), leading to lower WUA values during higher flows in August. Winter-run Chinook salmon fry rearing WUA starts to increase at flows above 10,000 cfs, and peak at flows around 30,000 cfs. The peak rearing flows are not expected to occur under the No Action Alternative or Alternative 3 during the fry rearing period in the Sacramento River below Keswick Dam. Winter-run Chinook salmon is the only Sacramento River salmonid race or species that shows this pattern.

The results of the winter-run Chinook salmon fry rearing habitat analysis suggest that Alternative 3 may have a minor (less than 2.5%) increase in estimated fry rearing habitat across all water year types and potentially no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Juvenile Rearing Habitat Analyses

Under Alternative 3, mean juvenile rearing WUA increases in wet, above normal, and critically dry water year types and decreases in below normal and dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 0.7% increase in critically dry water years. The largest reduction in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 0.5% decrease in below normal water year types.

The monthly median value of juvenile rearing WUA under Alternative 3 is similar to the No Action Alternative October through January (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are higher in January compared to the other months of juvenile rearing (Table O-248). Segment 5 has decreased WUA values when flows are between 5,000 and 10,000 cfs but the WUA values do not change as drastically with juvenile rearing in comparison to fry rearing. Winter-run Chinook salmon juvenile rearing WUA values start increasing at flows above 15,000 cfs, and peak at flows around 30,000 cfs. These peak rearing flows are not expected to occur under the No Action Alternative or Alternative 3 during the juvenile rearing period in the Sacramento River below Keswick Dam. Winter-run Chinook salmon is the only Sacramento River salmonid race or species that shows this pattern.

The results of suitable habitat analysis using the SIT LCM habitat models suggest that instream juvenile rearing habitat for winter-run Chinook salmon in the upper Sacramento River under Alternative 3 have a 0.8% to -3.0% difference between the months of October through January in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in November and the greatest reduction in estimated habitat may occur in January under Alternative 3 in comparison to the No Action Alternative.

The two winter-run Chinook salmon juvenile rearing habitat analyses suggest that Alternative 3 may have a negligible (less than 1%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and potentially no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles who generally are stronger swimmers. Alternative 3 shows a large and consistent reduction in stranding of winter-run juveniles from critically dry to wet water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*) and an increase from July to October (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Winter-run Chinook salmon fry rearing occurs primarily during summer through early fall, when flows tend to be less variable. The minimum rates of stranding for winter-run fry during wet years may result from increased stability in project operations related to greater reservoir storage levels. Alternative 3 has lower juvenile stranding of winter-run fry than the No Action Alternative in above normal, below normal, and critically dry water year types, but the reductions are not large (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The differences in mean stranding range from 7.8% lower stranding for Alternative 3 in above normal water year types to 1.9% higher in wet water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, winter-run Chinook salmon juvenile stranding for fry is lower under Alternative 3 in comparison to the No Action Alternative.

Survival and Travel Time: XT and Flow Survival Threshold Models

Del Rosario et al. (2013) found that ≥5% catch at the Knights Landing Rotary Screw Trap coincided with first day of flow of at least ~14,100 cfs (400 cm) at Wilkins Slough. Acoustically tagged fish released at locations in the upper Sacramento River under varying hydrological conditions are used to estimate survival probabilities and travel times rates. As fish migrate downstream towards the Delta, individuals encounter a range of environmental conditions and transition from reaches with unidirectional flow (upstream) to reaches with bidirectional flow (tidally driven, downstream). Outmigrating juveniles may be exposed to predation and as inflow declines and tidal influence moves upstream, travel time and distance may increase leading to higher exposure to predators. Michel et al. (2021) identified an optimal flow threshold condition favorable for outmigration for juvenile Chinook salmon, 10,712 cfs, which could provide an additional 2.7-fold increase in survival. Travel and survival rates of Chinook salmon in upper Sacramento River reaches are strongly correlated (Notch et al. 2020). Authors hypothesize one mechanism for the threshold is faster outmigration rates due to higher flows decrease exposure to possible predation (Michel et al. 2021).

Differences in daily flows (Upper Sacramento River Daily Operations Model, USRDOM) under Alternative 3 compared with the No Action Alternative may have effects on juvenile Chinook salmon's travel time and survival probabilities in the Upper Sacramento River. These possible differences were evaluated using several quantitative models: XT and Flow Survival Threshold.

Mean daily Sacramento River flows at Keswick Dam were equal or greater under Alternative 3 compared with the No Action Alternative in wet, above normal, and below normal water year types but were equal or less under Alternative 3 compared with the No Action Alternative in dry and critically dry water year types. Mean daily Sacramento River flows below Wilkins Slough (March 15th to June 15th) were equal or greater under Alternative 3 compared with the No Action Alternative (Attachment J.4, *XT Model;* Attachment J.5, *Flow Threshold Salmon Survival Model*). These two quantitative models provide results that demonstrate the flows under Alternative 3 compared with the No Action Alternative could increase survival and decrease travel time for outmigrating juvenile Chinook salmon on the Sacramento River limiting juveniles' exposure to predation and poor environmental conditions.

Annual mean survival probability under Alternative 3 was greater than annual mean survival probability under the No Action Alternative in wet, above normal, and critically dry water year types (16% greater in wet water year types and up to 25% greater in critically dry water year types). Annual mean survival probability under Alternative 3 was less than annual mean survival probability under the No Action Alternative in below normal and dry water year types (up to 3% less in dry water year types). The decrease would have a minimal effect while the increase (up to 25% greater) would have a large beneficial effect on outmigrating juvenile Chinook salmon. Under both scenarios, average annual mean survival probability was highest during the wet water year types and decreased as the water year type became drier. (Attachment J.5, *Flow Threshold Salmon Survival Model*).

Mean survival probability for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 3 was equal to the mean survival probability under the No Action Alternative in wet and below normal water year types. Survival

under Alternative 3 was 1% greater than survival under the No Action Alternative in above normal water year types and 1% less than survival under the No Action Alternative in critically dry and dry water year types. This range among water years from 1% less to 1% greater would not have an effect on outmigrating juvenile Chinook salmon. (Attachment J.4, *XT Model*).

Mean travel time (days) for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 3 was both greater than and less than mean travel time under the No Action Alternative (4-5% less in above normal water year type to the terminus of both reaches and 3-5% greater in wet water year type to the terminus of both reaches). This increase of 5% and decrease of 5% may have a minimal effect on outmigrating juvenile Chinook salmon, particularly dependent on predator presence and environmental conditions (e.g., water temperature) (Attachment J.4, *XT Model*).

<u>Winter-run Juvenile Production Index (JPI)</u>

Under Alternative 3, the mean predicted JPI is generally higher than No Action Alternative, ranging from 39.30% higher in 2017 to 49.26% lower in 2018. For years analyzed (2002-2021) roughly half (9) resulted in a higher JPI under Alternative 3 than the No Action Alternative. These results suggest that Alternative 3 is expected to have no effect, either positive or negative, on the number of juveniles produced annually when compared to the No Action Alternative.

<u>IOS: Fry Survival and Juvenile River Migration Survival</u>

Under Alternative 3, in critically dry water years, mean predicted winter-run Chinook salmon fry survival is 27.69% higher than when compared to the No Action Alternative. Alternative 3 reflects a change of 0.182 mean predicted winter-run Chinook salmon fry survival when compared to the No Action Alternative (0.65 under the No Action Alternative to 0.832 under Alternative 3). The change in mean predicted winter-run Chinook salmon fry survival in all other water year types was less than or equal to ± 0.003. Alternative 3 provides a substantial benefit to predicted survival of winter-run Chinook salmon fry during critically dry water years when compared to the No Action Alternative.

Under Alternative 3, in all water years, mean predicted river migration survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to 0.003. There is not a substantial difference in predicted river migration survival of winter-run Chinook salmon juveniles between Alternative 3 and the No Action Alternative.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 28 for Keswick Dam, Table 30 for Red Bluff Diversion Dam, and Table 32 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 34 for Keswick Dam, Table 36 for Red Bluff Diversion Dam, and Table 38 for Hamilton City.

Results for the two analyses are summarized in Table O-32. Table O-32, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 55.4°F to 68°F optimum temperature range analysis, there were zero to three month-water year type combinations (0% to 10% of total combinations during the period) with favorable results, depending on location, and there were zero to two combinations (0% to 6.7%) with unfavorable months, depending on location (Table O-32). For the 75.2°F upper incipient lethal temperature under Alternative 3, there would be no favorable or unfavorable results at any location. These results suggest that there would be slight positive water temperature-related effects of Alternative 3 on winter-run Chinook salmon juvenile rearing and outmigration in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have possible minor beneficial to minor adverse impacts on fry and juvenile rearing habitat, no impact to slightly beneficial impact on behavior (fry stranding, juvenile production index), and a possible substantial beneficial impact on fry survival particularly in critically dry years due to differences in flow. Alternative 3 relative to the No Action Alternative could have a minor adverse to minor beneficial impact on travel time and a possible substantial beneficial impact on individuals' survival in the upper Sacramento River due to differences in flow. Alternative 3 and the No Action Alternative are expected to have a slight beneficial impact on juvenile rearing and emigration due to differences in water temperature.

Adult Upstream Migration and Holding

Winter-run Chinook salmon adults enter the Sacramento River from the Delta and make their way to the upper Sacramento River, beginning as early as December through late spring (May/June) (see Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). They hold in the upper River within 10 to 15 miles of Keswick Dam until they are ready to spawn, which may extend through August (Windell et al. 2017). Most of the run passes Red Bluff Diversion Dam from January to May with the peak in mid-March (Hallock and Fisher 1985).

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

CalSim 3 Flows

Releases from Shasta Reservoir during November through early May may be reduced to conserve water for the May through October winter-run Chinook salmon and spring-run Chinook salmon spawning and incubation periods, resulting in reduced flow in the middle Sacramento River. Lower flow in the Sacramento River relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of winter-run adults into canals and behind weirs, increasing their stranding risk. Once the adults have migrated upstream on the Sacramento River, they reach holding habitat in the upper Sacramento River. In the upper Sacramento River, they are more directly affected by Shasta Reservoir and Keswick Dam operations designed to preserve cold water for the winter-run Chinook salmon and spring-run Chinook salmon spawning and incubation periods.

During the December through May/June period of adult winter-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 3 at Sacramento River below Keswick Dam, below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough would range from less than to greater than flows under the No Action Alternative, depending on month and water year type. At Keswick Dam, Red Bluff Diversion Dan, and Hamilton City flows under Alternative 3 in June under all water year types were lower than flows under the No Action Alternative and in December were greater than flows under the No Action Alternative. At the above three locations, flows under Alternative 3 in more dry water year types (dry and critically dry) were less than the No Action Alternative in February, March, April and May. At Wilkins Slough flows under Alternative 3 December through March in all water year types were similar to or greater than flows under the No Action Alternative, up to 7% greater in January of a critically dry water year type. Flows under Alternative 3 in April through June varied from 37% greater to 28% lower compared to the No Action Alternative. Flows in July at Hamilton City and Wilkins Slough under Alternative 3 would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 3 between December and May/June would be greater than 4,700 cfs at Wilkins Slough and greater than 8,400 cfs at Hamilton City (Table O-248, Table O-249, Table O-251, Table O-250).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range for winter-run Chinook salmon adult migration and holding are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 4 for Keswick Dam, Table 6 for Red Bluff Diversion Dam, and Table 8 for Hamilton City.

Results are summarized in Table O-33. Table O-33, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Table O-33 indicates that, under Alternative 3, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at all locations, except Hamilton City, at which there was one combination (3.3%) with an unfavorable result (Table O-33). These results suggest that there would be minimal effects of Alternative 3 on water temperature conditions for winter-run Chinook salmon adult migrants in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a minor adverse to minor beneficial impact, depending on location and month, on upstream migrating and holding adult winter-run Chinook salmon, as average monthly flows at Hamilton City and Wilkins Slough are high enough to allow upstream passage. Alternative 3 and the No Action Alternative are expected to have no impact to minimal adverse impacts on upstream migrating and holding adult winter-run Chinook salmon due to differences in water temperature.

O.6.8.2 Bay-Delta

Juvenile Rearing and Emigration

Rearing winter-run Chinook salmon are present in the Delta from October to May (see Section O.1.9.1.1, *Winter-run Chinook Salmon, Sacramento River ESU*). Key habitat attributes relevant to seasonal operations in the Delta include out-migration cues and entrainment risk. Juveniles enter the Delta primarily during December through April and most emigrate past Chipps Island by the end of April but can potentially exit as late as May (Brandes and McLain 2001; del Rosario et al. 2013). A critical assumption in these analyses is LAD criteria used to identify juveniles (vs genetic ID) are sufficient to represent juveniles' downstream migration patterns.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Differences in hydrology in the Delta under Alternative 3 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using two quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions.

<u>Zone of Influence</u>

For a full description of Zone of Influence model background, see Section O.4.8.2, *Sacramento River Winter-run Chinook Salmon ESU, Juvenile Rearing and Emigration in the Bay-Delta*. The following section covers discussion of differences in spatial extent of export influence presented as a direction between Alternative 3 and the No Action Alternative. For a detailed explanation of methods and analyses, see Attachment I.3, *Delta Export Zone of Influence Analysis*.

The proportional overlap of Alternative 3 (pumping vs no pumping) was less than the proportional overlap of the No Action Alternative (pumping vs no pumping) at Turner Cut and San Joaquin River at Jersey Point under the two more positive OMR bins (-2,000 and -3,500; Attachment I.3, *Delta Export Zone of Influence Analysis*). The proportional overlap of Alternative 3 (pumping vs no pumping) was less than the proportional overlap of the No Action Alternative (pumping vs no pumping) at Old River at Middle River under the two more positive OMR bins (-2,000 and -3,500).

With incremental decreases in OMR under Alternative 3 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping.

<u>Flow into Junctions</u>

For a full description of Flow into Junctions model background, see Section O.4.8.2, *Sacramento River Winter-run Chinook Salmon ESU, Juvenile Rearing and Emigration in the Bay-Delta*. The following section covers discussion of the Central Valley Project and Head of Old River junctions. An expanded set of junction analysis results can be found in Attachment I.10, *Flow into Junctions*.

Under Alternative 3 in the -2,000 and -3,500 OMR bins, predicted proportion of flow entering the Central Valley Project (CVP) is greater than the No Action Alternative, and less than the No Action Alternative in the -5,000 and <-5,500 OMR bins. Changes in predicted proportion of flow entering the CVP when OMR was -2,000, -3,500, and -5,000 were less than ± 0.0406, indicating a negligible difference from the No Action Alternative. However, when OMR was <-5,500 the change in flow into CVP was -0.0933, indicating that slightly less flow will be routed into CVP under Alternative 3 than when compared to the No Action Alternative.

Under Alternative 3 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the Head of Old River (HOR) is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.0404, indicating a negligible difference between Alternative 3 and the No Action Alternative.

Summary

Alternative 3 relative to the No Action Alternative are expected to influence flow into the HOR and CVP junctions due to differences in flow. Under Alternative 3, no change to possibly less flow into CVP under OMR -3,500; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 3 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Winter-run Chinook Salmon

Salvage Density and Negative Binomial

Predictions from the salvage density model for genetic and LAD winter-run Chinook salmon include mean monthly total exports. Predictions from the negative binomial loss model for LAD winter-run Chinook salmon include mean monthly total exports and mean monthly San Joaquin River flows at Vernalis. Table O-253 shows modeled mean monthly total exports at SWP and CVP and Table O-263 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of genetic winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types for Alternative 3 was less than predicted average monthly loss under the No Action Alternative for wet, above normal, and below normal water year types with up to a 57% reduction in predicted loss for wet water year types. Predicted loss from Alternative 3 compared to the No Action Alternative for genetic winter-run Chinook salmon for dry and critically dry water year types increased with up to a 26% increase in predicted loss for dry water year types (Table O-36). Predicted average monthly loss of genetic winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April for Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for all water year types with a reduction of up to 68% for the critically dry water year types (Table O-37). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly loss of LAD winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through April of all water year types Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for wet, above normal, and below normal water year types, with up to a 55% reduction in predicted loss for wet water year types. Predicted loss of LAD winter-run Chinook salmon from Alternative 3 compared to the No Action Alternative at Banks for dry and critically dry water year types increased with up to a 13% increase in predicted loss (Table O-34). Predicted average monthly loss of LAD winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for all water year types. Predicted loss of LAD winter-run Chinook salmon from Alternative 3 compared to the No Action Alternative had a reduction of up to 60% for critically dry water year types (Table O-35). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly salvage of LAD winter-run Chinook salmon at the Delta fish collection facilities for the months of December through April under Alternative 3 was lower than predicted average monthly salvage under the No Action Alternative for all water year types except for the above normal water year types which had an increase of 4%. Predicted loss for genetic and LAD winter-run Chinook salmon under Alternative 3 compared to the No Action Alternative was less for all other water year types, with up to a 53% reduction in loss for wet water year types (Table O-38). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

Winter-run Chinook Salmon Coded Wire Tag Salvage Model

The Winter-run Chinook Salmon Coded Wire Tag (CWT) Proportional Salvage Model was developed to estimate the fraction of juvenile winter-run Chinook salmon in the Delta predicted to be salvaged based on hydrologic conditions and fish size. To apply this model to hydrologic scenarios outside of those used to construct the model, a fixed number of winter-run Chinook salmon entering the Delta each month was used. The raw output of the model is the number of fish salvaged. However, an offset variable was used to convert this number to a proportion. In this way, the model predicts the magnitude of salvage independent of the number of fish that may actually be in the Delta during a given month.

Predicted mean of annual and monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for all months October through May under Alternative 3 in all water year types, varied from positive to negative between months when compared to the No Action Alternative (Attachment I.9, *Winter-run Chinook Salmon Coded Wire Tag Salvage Model*). Salvage is predicted to increase in wet years under Alternative 3 when compared to the No Action Alternative, however all predicted proportion salvaged are less than ± 0.01 in all months and years. Overall, there is not a substantial difference in predicted proportion salvaged between Alternative 3 and the No Action Alternative.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a potential beneficial impact on the entrainment of genetically and LAD identified juvenile winter-run Chinook salmon in the Delta at both fish facilities due to differences in flow, supported by results from two quantitative models. The beneficial impact under Alternative 3 occurs in all water year types

at Jones for both LAD and genetically identified winter-run Chinook salmon. However, possible adverse impacts occur at Banks in water year types with poor conditions (dry, critically dry). A third model suggests no impact under Alternative 3 relative the No Action Alternative due to differences in flow on predicted salvage proportion of juvenile winter-run Chinook salmon.

Potential Changes to Routing of Winter-run Chinook Salmon

Winter-run Chinook salmon travel through different migratory pathways. Using a conceptual model, a single fish in any location could have arrived at that location via one of several pathways (Figure O-14). For example, a fish observed salvage could have arrived via one of many pathways (e.g., Sacramento Origin via the mainstem Sacramento then below Cache Slough, then South Delta or via the DCC and Central Delta then the South Delta). If a proportion of fish is higher down a migratory pathway documented as a route with higher survival rates for juvenile salmonids, then fish migrating through that route will likely have a better chance of surviving to the ocean than fish migrating through a sub-optimal route (e.g., experiencing potential entrainment into the Central Delta through the DCC or Georgiana Slough).

Empirical estimates of acoustically tagged late-fall run Chinook salmon from Coleman National Fish Hatchery (CNFH) tracked in December 2006, January and December 2007, and January 2008 experienced routing in the mainstem Sacramento from 35.2% to 49.8%, through Georgiana Slough 0% to 31.1%, and through the Sutter and Steamboat sloughs 19.8% to 41.4% (Perry 2010). Results suggest the proportion of fish entering each route generally follows river flow but is not always in agreement with the proportion of discharge entering that route, suggesting another parameter may affect fish routing. Release groups experienced different discharge and export conditions leading to wide ranges in routing probabilities. Other studies also report proportional flow is a strong predictor of route selection (Kemp et al. 2005; Cavallo et al. 2015; Romine et al. 2021). Additionally, variables like DCC gate status (open / closed) will change routing and survival probabilities for fish traveling along the mainstem Sacramento River when they get to both Georgiana Slough and the DCC junctions. Newman and Brandes (2010) reported that exports affect routing of fish released in Georgiana Slough more than fish released at Ryde (upstream of Georgiana Slough on the Sacramento River) and the fraction of fish released in Georgiana Slough recovered at the fish collection facilities increased with increased exports.

Differences in monthly flows on the Sacramento River under Alternative 3 compared with the No Action Alternative may have effects on juvenile Chinook salmon's routing and survival probabilities in the Sacramento River.

<u>STARS</u>

Average Sacramento River flows at Freeport December through May are greater under Alternative 3 compared with the No Action Alternative. The STARS model is responsive to modeled Freeport flows and daily operations of the DCC gates, both obtained from CalSim 3.

The STARS model provides predictions of routing and survival probabilities, in this section routing results are discussed. In the "survival" section survival results are discussed. Mean proportion of particles routed to the Interior Delta via either Georgiana Slough or the DCC), averaged across all water year types by month under Alternative 3 was less than the No Action Alternative for all months December through April (up to 3.4% less in April) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). The decrease in proportion of particles

routed to the Interior Delta under Alternative 3 could have a minimal beneficial effect on outmigrating juveniles.

ECO-PTM

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under Alternative 3 ranged from less than the No Action Alternative (up to 18% less under -5,000 cfs) to greater than the No Action Alternative (up to 5% greater under -3,500 cfs) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in Attachment I.7, *ECO-PTM*. The decrease in routing to the Interior Delta could have a large beneficial effect on outmigrating juveniles while the increase in routing could have an adverse effect on outmigrating juveniles.

Summary

The two flow-based quantitative models suggest depending on considered variables, flows under Alternative 3 compared with the No Action Alternative may be adverse or beneficial for outmigrating juvenile winter-run Chinook salmon when results are binned by OMR grouping. Alternative 3 relative to the No Action Alternative using STARS suggests possible minimal beneficial impact on routing into the Interior Delta in all water year types in all months December through April, due to differences in flow. Alternative 3 and the No Action Alternative using ECO-PTM suggest an adverse or beneficial impact with a smaller proportion routed to Interior Delta between December and March, particularly under OMR -5,000.

Potential Changes to Through Delta Survival of Winter-run Chinook Salmon

Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. Juvenile Chinook salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010, 2018).

STARS

Average Sacramento River flows at Freeport December through May are greater under Alternative 3 compared with the No Action Alternative. The STARS model is responsive to modeled Freeport flows and daily operations of the DCC gates, both obtained from CalSim 3.

The STARS model provides predictions of routing and survival probabilities, in this section survival results are discussed. In the "routing" section routing results are discussed. Mean predicted through-Delta survival of particles across all routes, averaged across all water year types by month under Alternative 3 was greater than the No Action Alternative in all months December through April (up to 3.5% in April) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). This increase in survival could have a beneficial effect on outmigrating juveniles, particularly if environmental conditions are sub-optimal.

ECO-PTM

Mean through-Delta percent survival December through March under Alternative 3 ranged from less than the No Action Alternative (up to 9% less under -3,500 cfs) to greater than the No Action Alternative (up to 16% more under <-2,000 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in Attachment I.7, *ECO-PTM*. The increase in survival under some OMR conditions could have a large beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have a large adverse effect on outmigrating juveniles.

Delta Passage Model

Under Alternative 3, in all water year types, predicted mean survival of winter-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). The change in mean predicted mean survival to Chipps Island in all water year types is less than or equal to ± .022.

IOS: Through-Delta Survival

Under Alternative 3 in all water years, mean predicted through Delta survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative. The change in mean predicted river migration survival in all water year types less than or equal to .018.

OBAN: Delta Survival

Delta survival under Alternative 3 was greater than under the No Action Alternative (19%, Table O-30). This increase would have a beneficial effect on outmigrating juvenile winter-run Chinook salmon.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a potential adverse or beneficial impact on survival of outmigrating juvenile winter-run Chinook salmon, due to differences in flow, and depending on OMR grouping and model.

O.6.9 Central Valley Spring-run Chinook Salmon ESU

O.6.9.1 Sacramento River

Spawning and Egg/Alevin Incubation

Spring-run Chinook salmon adults spawn from August through October (Williams 2006) with peak spawning in September (see Section O.1.3.2). Monitoring spring-run Chinook salmon spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from fall-run Chinook salmon. Most spring-run Chinook salmon spawning occurs between the Keswick Dam and Ball Ferry Bridge (NMFS 2017c). Fry emergence occurs up to three months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating spring-run Chinook salmon eggs and alevins potentially occur from August through January, peaking in December.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 3, mean spawning WUA is higher in wet, above normal, and critically dry water year types and lower in below normal and dry water year types (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 3 and the No Action Alternative is a 5.7% increase in above normal water year types. The largest reduction in estimated spawning habitat is a -2.5% decrease for Alternative 3 in below normal water year types (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The monthly median value of spawning WUA under Alternative 3 is similar to the No Action Alternative in September and October, and lower in August (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA for all of the modeled alternatives are substantially lower in August than in September or October. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in August than in the other two months (Table O-248). This results in lower spawning WUA results because the fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), which were used to estimate spring-run Chinook salmon spawning WUA, peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of suitable habitat availability analysis using the SIT LCM habitat models indicate that spawning habitat for spring-run Chinook salmon in the upper Sacramento River may not a limiting factor under both the No Action Alternative and Alternative 3 (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The two spawning habitat analyses based on CalSim 3 simulated flows suggest that Alternative 3 may have a minor (5.7%) increase in estimated spawning habitat during above normal water year types when compared to the No Action Alternative, but that spawning habitat may not be a limiting factor for spring-run Chinook salmon in the mainstem upper Sacramento River.

SIT Spring-run Lifecycle Model: Spawner Abundance

In the CVPIA spring-run SIT Chinook salmon life cycle model, mean spring-run Chinook salmon spawner abundance in the Central Valley under Alternative 3 in Chinook salmon spawner abundances are similar to the No Action Alternative in the Central Valley. The largest increase in abundance between the No Action Alternative and Alternative 3 was a 0.2% increase in critically dry water year types and 0.6% decrease in above normal water year types (Attachment F.3, *CVPIA SIT Spring-run LCM*). Under Alternative 3 and the No Action Alternative there is a year-to-year abundance decrease in dry years and an increase in all other water year types; a negative value indicates a decrease in annual spawner abundance. Over the full model run period (1980–1999), abundance under Alternative 3 was equal to abundance under the No Action Alternative. Overall the spawner abundance predicted by the CVPIA Spring run life cycle model is expected to be similar under Alternative 3 and the No Action Alternative.

Redd Dewatering Analysis

Under Alternative 3, the spring-run Chinook salmon redd dewatering results show a consistent reduction in redd dewatering potential from wetter to drier water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation is expected for spring-run Chinook salmon because their spawning occurs in the fall, with incubation extending into early winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater estimates of redd dewatering potential. In drier winters, flow fluctuations are reduced and fewer redds are potentially dewatered. Most differences between the No Action Alternative and Alternative 3 are reductions, with a maximum reduction of 17.9% in above normal water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). Other large differences include a 10.8% reduction for wet water years and a 9.2% increase for dry water years. For individual months, redd dewatering for September spawning is moderately higher than that for October spawning (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that redd dewatering potential under Alternative 3 would be lower than that under the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 48 for Keswick Dam and Table 50 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 54 for Keswick Dam and Table 56 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during September through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 60 for Keswick Dam and Table 62 for Red Bluff Diversion Dam.

Results for the three analyses are summarized in Table O-39. Table O-39, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 42.1°F to 55°F spawning initiation range analysis, there were nine and zero month-water year type combinations (25.7% and 0% of total combinations during the period) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively, and there were no combinations with unfavorable results at either location (Table O-39). For the 59.9°F pathogen virulence threshold, there were three and 11 combinations (8.6% and 31.4%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively, and there were zero and two combinations (0% and 5.7%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. For the 42.8°F to 56°F range for egg incubation and fry emergence, there was one combination (2.9%) with favorable results at each location, and one and zero combinations with unfavorable results (2.9% and 0%) below Keswick Dam and at Red Bluff Diversion Dam, respectively. These results suggest that there

would be positive effects of Alternative 3 on spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a minor beneficial impact on spring-run Chinook salmon spawning, spawner abundance, and egg/alevin incubation (mortality) due to differences in flow. Flow for spawning habitat is not expected to be a limiting factor for spring-run Chinook salmon. Redd dewatering has a minor beneficial impact under Alternative 3 compared to the No Action Alternative. Water temperatures for spawning and egg/incubation and pathogen virulence have a beneficial impact under Alternative 3 compared to the No Action Alternative.

Juvenile–Yearling Rearing and Emigration

Spring-run Chinook salmon juveniles rear in the Sacramento River primarily from November through June and most emigrate to the Delta during December and again in March and April (Roberts 2007) (see Section O.1.3.2, *Spring-run Chinook Salmon*). Migratory cues, such as increased flow and/or turbidity from runoff, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (NMFS 2009a). Inundated floodplain habitats have been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001a, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 3, mean fry rearing WUA increases in below normal and dry water year types and decreases in wet, above normal, and critically dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increases in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 0.8% increase in dry water year types. The largest reduction in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 1.5% decrease in above normal water year types.

There are some differences in fry rearing WUA on a monthly scale between Alternative 3 and the No Action Alternative. In December and February, there is a 5% reduction in the median value of fry rearing WUA under Alternative 3 in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). In November, there is a 5% increase in the median value of fry rearing WUA under Alternative 3 in comparison to the No Action Alternative. Alternative 3 and the No Action Alternative are similar during the other fry rearing months. Fry rearing WUA median values for all the modeled alternatives are similar across December, January, and March, which are important months for rearing. The results during these three months show little variation in the third quartile of the WUA distributions. This limited variation occurs because the fry rearing WUA curves peak at the lowest flows encountered in the river and Keswick Dam flow releases are frequently low during these months in critically dry years when Shasta Reservoir is operated to rebuild storage volume (Table O-248). The first

quartile is much wider because a greater range of flows affect the fry rearing WUA values below the median. November and April have the lowest median WUA values across all alternatives.

The results of the spring-run Chinook salmon fry rearing habitat analysis suggest that Alternative 3 may have a minor (less than 2%) increase and/or decrease in estimated spring-run Chinook salmon fry rearing habitat across all water year types in comparison to the No Action Alternative. There are some differences in estimated rearing WUA habitat when looking at a monthly scale, with December and February having a minor (5%) decrease in estimated fry rearing habitat and November with a minor (5%) increase in estimated fry rearing habitat.

Juvenile Rearing Habitat Analyses

Under Alternative 3, mean juvenile rearing WUA increases in wet water year types and decreases in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 1.1% increase in wet water year types. The largest reduction in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 1.7% decrease in critically dry water year types.

The monthly median value of juvenile rearing WUA under Alternative 3 is similar to the No Action Alternative January through May (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under all of the modeled alternatives are similar for January through March, but they are generally lower for April and May. For the January through March period, as described above for spring-run Chinook salmon fry rearing WUA, the third quartiles of the WUA distributions have high values and reduced variation. This occurs because, as described for the fry rearing WUA curves, the juvenile rearing WUA curves peak at the lowest flows encountered in the river and low flows are frequent during January through March in dry and critically dry years when Shasta Reservoir is operated to rebuild storage (Table O-248).

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for spring-run Chinook salmon in the upper Sacramento River show a 3.3% to -3.0% difference between the months of January and May (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in April and the greatest reduction in estimated habitat may occur in January under Alternative 3 in comparison to the No Action Alternative.

The results of the two spring-run Chinook salmon juvenile rearing habitat analyses suggest that Alternative 3 may have a minor (equal to or less than 3.3%) increase and/or decrease in estimated spring-run Chinook salmon juvenile rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who generally are stronger swimmers. Alternative 3 shows a large increase in mean stranding of spring-run Chinook salmon fry from critically dry, dry, and below normal water years to above normal and wet years (Attachment L.5,

Sacramento River Juvenile Stranding Analysis). Spring-run Chinook salmon fry rearing occurs primarily during late fall and winter. For individual months, Alternative 3 shows the highest stranding in November and February (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher mean stranding levels for spring-run Chinook salmon fry during February and in wetter water year types likely results because of periodic storms and high runoff that produce increased variability of flow. Fry stranding means are similar between Alternative 3 and the No Action Alternative in all water year types except for a 7.8% increase under Alternative 3 in critically dry water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, spring-run Chinook salmon stranding of fry is similar under Alternative 3 in comparison to the No Action Alternative, except for an increase in stranding under critically dry water years.

Survival and Travel Time: XT and Flow Survival Threshold Models

Differences in daily flows (Upper Sacramento River Daily Operations Model, USRDOM) under Alternative 3 compared with the No Action Alternative may have effects on juvenile Chinook salmon's travel time and survival probabilities in the Upper Sacramento River. These possible differences were evaluated using several quantitative models. For a detailed description of how flows under Alternative 3 may impact juveniles and yearlings' travel time and survival probabilities in the Upper Sacramento River, see Alternative 3, Sacramento River Winter-run Chinook Salmon ESU (Section O.6.8.1).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for juvenile growth, smoltification, and predation vulnerability during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 66 for Keswick Dam, Table 68 for RBDD, and Table 70 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating juveniles during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 74 for Keswick Dam, Table 76 for RBDD, and Table 78 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for yearling growth, smoltification, and predation vulnerability are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 82 for Keswick Dam during April through December, Table 84 for RBDD during April through December, and Table 98 for Hamilton City during October through December (migration only). Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating yearlings are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 88 for Keswick Dam during April through December, Table 90 for RBDD during April through December, and Table 106 for Hamilton City during October through December (migration only).

Results for the four analyses are summarized in Table O-40. Table O-40, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F juvenile optimum water temperature range under Alternative 3, there were zero to one month-water year type combinations (0% to 2.5% of total combinations during the period) with favorable results depending on location (Table O-40). There were zero to six combinations (0% to 15.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 3, there would be no combinations with either favorable or unfavorable results at any location. For the 55.4°F to 68°F yearling optimum temperature range under Alternative 3, there would be zero to one combinations with favorable results (0% to 6.7%) with favorable results depending on location. There would be zero to eight combinations (0% to 17.8%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating yearlings under Alternative 3, there would be no combinations with either favorable or unfavorable results at any location.

These results indicate that there would generally be a mix of minor favorable and unfavorable water temperature-related effects under Alternative 3 on optimum water temperatures on juveniles and yearlings, with the exception of Keswick Dam, where there would be negative effects on both juveniles and yearlings. There would be negligible effects of Alternative 3 on lethal water temperatures.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor adverse impacts on spring-run Chinook salmon juvenile and yearling rearing habitat due to differences in flow. Stranding is similar in comparison to the No Action Alternative except in critically dry years. Mean annual survival would be increased, and mean survival and travel time would have a minimal impact on juvenile and yearling spring-run Chinook salmon. Water temperatures for optimum juvenile and yearling rearing is a mix, except at Keswick Dam, where water temperatures could have an adverse impact on both life stages. There are no impacts related to the critical upper temperature limit for juveniles and yearlings.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon enter the San Francisco Estuary from the Pacific Ocean to begin their upstream spawning migration in late January and early February (California Department of Fish and Wildlife 1998). Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). While maturing, adults hold in deep pools with cold water. Documentation of holding locations in the Sacramento River was not identified.

Spring-run Chinook salmon adults enter the Sacramento River from March to September, primarily in May and June (Moyle 2002; Yoshiyama et al. 1998). In the upper Sacramento River, migration extends from mid-March through July with peak migration in late May and early June (California Department of Fish and Wildlife 1998).

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

During the January through June/July period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 3 at Sacramento River below Keswick Dam, below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough would generally be similar to or greater than flows under the No Action Alternative, from January through March,

except during February of a critically dry water year type below Keswick Dam when flows would be up to 12% less. Flows under Alternative 3 in April through July would be less than 5% greater than flows under the No Action Alternative at all four locations, except during wet and above normal years in May when flows would be up to 37% greater at Wilkins Slough. Flows at all sites range from -5% to -28% at Wilkins Slough in June during an above normal year. Flows at Hamilton City under Alternative 3 would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 3 between January and June/July would be greater than 5,500 cfs at Wilkins Slough (except in June) and greater than 7,500 cfs (except in June) at Hamilton City (Table O-248, Table O-249, Table O-250, Table O-251).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during March through September are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 40 for Keswick Dam, Table 42 for RBDD, and Table 44 for Hamilton City.

Results for the analysis are summarized in Table O-41. Table O-41, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3, there were zero to two month-water year type combinations (0% to 5.7% of total combinations during the period) with favorable results and zero to one combination (0% to 2.9%) with unfavorable results, depending on location (Table O-41). These results suggest that there would be mostly negligible water temperature-related effects of Alternative 3 on spring-run Chinook salmon migration and holding in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have some adverse impacts during June and July, little to no impact from January to April, and a beneficial impact in May during wet and above normal water years, depending on location and month, on upstream migrating and holding adult spring-run Chinook salmon. Average monthly flows at Hamilton City and Wilkins Slough are high enough to allow upstream passage. Differences in water temperatures between Alternative 3 and the No Action Alternative are expected to have a negligible impacts on upstream migrating and holding adult spring-run Chinook salmon.

O.6.9.2 Clear Creek

Spawning and Egg Incubation

Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities to promote higher oxygen levels. Spawning in Clear Creek normally occurs between mid-August and early October, peaking in September (Moyle 2002).

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 3, mean spawning WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean spawning WUA under Alternative 3 in comparison to the No Action Alternative. The largest reduction in estimated spawning habitat is a 21.2% decrease in wet water year types. On average across all water year types, there is a 19.9% reduction in estimated spawning habitat under Alternative 3.

The mean values of spawning WUA by month are lower under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). October is expected to have higher WUA values under Alternative 3.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for spring-run in Clear Creek may be a limiting factor under all of the modeled alternatives and that spawning habitat may decrease 15.3-20.1% in September and October for Alternative 3 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The two spawning habitat analyses suggest that Alternative 3 may have an adverse effect, as spring-run Chinook salmon spawning habitat may decrease on average by 19.9% across all water year types in Clear Creek when compared to the No Action Alternative, and that spawning habitat may be a limiting factor for spring-run Chinook salmon in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 52 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 58 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during September through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 6 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-42. Table O-42, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-42). For the 59.9°F pathogen virulence threshold, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown

Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on spring-run Chinook salmon spawning in Clear Creek.

Summary

Alternative 3 relative to the No Action Alternative is expected to include a decrease in flows and moderate to adverse impact on spawning habitat area. Alternative 3 relative to the No Action Alternative is expected to have a negligible impact on spawning, pathogen virulence, or egg incubation and fry emergence due to differences in water temperature.

Juvenile–Yearling Rearing and Emigration

While the majority of juvenile spring-run Chinook salmon outmigrate as fry, a proportion rears in Clear Creek through the spring and summer and emigrates as subyearlings with the first rainstorms in the fall or winter following their birth (NMFS 2014a). Spring-run Chinook salmon outmigration from Clear Creek occurs during late October through late April with peak emigration of juveniles occurring in November, and few fish exiting through the end of May.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 3, mean fry rearing WUA increases in all water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 7.6% increase in dry water year types. There are no anticipated reductions in mean fry rearing WUA under Alternative 3 in comparison to the No Action Alternative.

The mean values of fry rearing WUA by month are similar to or higher under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). January, February, and March are expected to have the highest fry rearing WUA values.

The results of the spring-run fry rearing habitat analysis suggest that Alternative 3 may have a minor (less than 8%) increase in estimated spring-run Chinook salmon fry rearing habitat across all water year types in Clear Creek.

Juvenile Rearing Habitat Analyses

Under Alternative 3, mean juvenile rearing WUA decreases in all water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 3 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 7.7% decrease in critically dry water year types. On average across all water year types, there is a 4.7% reduction in estimated juvenile rearing habitat under Alternative 3.

The mean values of juvenile rearing WUA by month are lower June through August and higher in April and May under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). May is expected to have the highest juvenile rearing WUA values under Alternative 3 throughout the juvenile rearing period.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for spring-run Chinook salmon in Clear Creek may decrease 13.6-20.3% during the summer months (June through August) but may increase 5.5-14.2% in the spring months April and May under Alternative 3 compared to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest decrease in estimated juvenile rearing habitat may occur in August and the greatest increase in estimated juvenile rearing habitat may occur in May.

The results of the two spring-run Chinook salmon juvenile rearing habitat analyses suggest that Alternative 3 may have a minor adverse effect, as rearing habitat may decrease up to 7.7% across all water year types in comparison to the No Action Alternative, and that there may be increases to habitat in the spring and reductions in habitat in the summer in Clear Creek.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for juvenile growth, smoltification, and predation vulnerability during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 72 below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating juveniles during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 80 below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for yearling growth, smoltification, and predation vulnerability are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 86 below Whiskeytown Dam April through December. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating yearlings are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 92 below Whiskeytown Dam for April through December.

Results for the four analyses are summarized in Table O-43. Table O-43, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F juvenile optimum temperature range under Alternative 3, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-43). For the 75.2°F UILT for rearing and migrating juveniles, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam. For the 55.4°F to 68°F yearling optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam. For the 75.2°F UILT for rearing and migrating

yearlings, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on juvenile and yearling rearing and holding in Clear Creek.

Summary

Alternative 3 relative to the No Action Alternative is expected have a minor beneficial impact fry rearing habitat, an adverse impact on juvenile rearing habitat during the summer months, and a beneficial impact on juvenile rearing habitat during the spring months, due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have a negligible impact on rearing and emigration due to differences in water temperature.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon migrate into Clear Creek from April to August, and peak passage occurs in May and June (Clear Creek Technical Team 2018; Giovannetti et al 2013). Adults distribute throughout Clear Creek and hold in deep pools throughout the summer from Whiskeytown Dam (river mile 18.3) as far downstream as river mile 4.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

During the April through August period of adult spring-run Chinook salmon immigration and holding in Clear Creek, the mean monthly flows under Alternative 3 will be increased in April and May but decreased from June to August. Flows from June to August will range from 94 cfs during a critically dry year in August to 232 cfs in June (Table O-257).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during March through September are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 46 below Whiskeytown Dam.

Results for the analysis are summarized in Table O-44. Table O-44, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 37.9°F to 68°F successful adult migration range, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-44). These results suggest that there would be negligible water temperature-related effects of Alternative 3 on spring-run Chinook salmon adult upstream migration and holding in Clear Creek.

Summary

Alternative 3 relative to the No Action Alternative may have an adverse impact from June to August on upstream migrating and holding, due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on upstream migrating and holding due to differences in water temperature.

O.6.9.3 Bay-Delta

Juvenile–Yearling Rearing and Emigration

Juvenile spring-run Chinook salmon show two distinct out-migration patterns in the Central Valley: out-migrating to the Delta and ocean during their first year of life as YOY or holding over in their natal streams and out-migrating the following fall/winter as yearlings. YOY spring-run Chinook salmon presence in the Delta peaks during April and May, as suggested by the recoveries of Chinook salmon in the CVP and SWP salvage operations and the Chipps Island trawls of a size consistent with the predicted size of spring-run fish at that time of year.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Zone of Influence

Differences in hydrology under Alternative 3 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. With incremental decreases in OMR under Alternative 3 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under Alternative 3 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 3, Sacramento River Winter-run Chinook Salmon ESU (Section O.6.8.2, *Zone of Influence*).

Flow into Junctions

For a full description of Flow into Junctions model background, see Section O.4.8.2, *Sacramento River Winter-run Chinook Salmon ESU, Juvenile Rearing and Emigration in the Bay-Delta*. The following section covers discussion of the Central Valley Project and Head of Old River junctions. An expanded set of junction analysis results can be found in Attachment I.10, *Flow into Junctions*.

Under Alternative 3 in the -2,000 and -3,500 OMR bins, predicted proportion of flow entering the Central Valley Project (CVP) is greater than the No Action Alternative, and less than the No Action Alternative in the -5,000 and <-5,500 OMR bins. Changes in predicted proportion of flow entering the CVP when OMR was -2,000, -3,500, and -5,000 were less than ± 0.0406, indicating a negligible difference from the No Action Alternative. However, when OMR was <-5,500 the change in flow into CVP was -0.0933, indicating that slightly less flow will be routed into CVP under Alternative 3 than when compared to the No Action Alternative.

Under Alternative 3 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the Head of Old River (HOR) is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.0404, indicating a negligible difference between Alternative 3 and the No Action Alternative.

Summary

Alternative 3 relative to the No Action Alternative is expected to influence flow into the HOR and CVP junctions. Under Alternative 3, no change to possibly less flow into CVP under OMR -3,500; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 3 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Spring-run Chinook Salmon

Differences in exports and flows under Alternative 3 compared with the No Action Alternative may have effects on juvenile winter-run Chinook salmon entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using two quantitative models: Salvage Density and Negative Binomial.

Salvage Density and Negative Binomial

Predictions from the salvage density model for genetic and LAD spring-run Chinook salmon include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP and Table O-263 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of genetic spring-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types for Alternative 3 was less than predicted average monthly loss under the No Action Alternative for wet, above normal, and below normal water year types with up to a 57% reduction in predicted loss for wet water year types. Predicted loss from Alternative 3 compared to the No Action Alternative for genetic spring-run Chinook salmon for dry and critically dry water year types increased with up to a 26% increase in predicted loss for dry water year types (Table O-47). Predicted average monthly loss of genetic spring-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April for Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for all water year types with a reduction of up to 68% for the critically dry water year types (Table O-47). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly loss of LAD spring-run Chinook salmon at SWP Banks Pumping Plant for all the months December through April of all water year types Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for wet, above normal, and below normal water year types, with up to a 55% reduction in predicted loss for wet water year types. Predicted loss of LAD spring-run Chinook salmon from Alternative 3 compared to the No Action Alternative at Banks for dry and critically dry water year types increased with up to a 13% increase in predicted loss (Table O-45). Predicted average monthly loss of LAD spring-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for all water year types. Predicted loss of LAD spring-run Chinook salmon from Alternative 3 compared to the No Action Alternative had a reduction of up to 60% for critically dry water year types (Table O-45). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly salvage of LAD spring-run Chinook salmon at the Delta fish collection facilities for the months of December through April under Alternative 3 was lower than predicted average monthly salvage under the No Action Alternative for all water year types except for the above normal water year types which had an increase of 4%. Predicted loss for genetic and LAD spring-run Chinook salmon under Alternative 3 compared to the No Action Alternative was less for all other water year types, with up to a 53% reduction in loss for wet water year types (Table O-47). For detailed information on average monthly salvage by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a potential beneficial impact due to differences in flow on the entrainment and salvage of the genetic and LAD identified juvenile spring-run Chinook salmon in the Delta at both fish facilities, supported by results from the two quantitative models.

Potential Changes to Routing of Spring-run Chinook Salmon

ECO-PTM

Alternative 3 relative to the No Action Alternative may have effects due to differences in flow on juvenile Chinook salmon's routing to Interior Delta via Georgiana Slough in the Delta. This possible difference was evaluated using ECO-PTM. For a detailed description of how flows under Alternative 3 may impact spring-run Chinook salmon routing, see Alternative 3, Sacramento River Winter-run Chinook Salmon ESU (Section O.6.8.2).

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under Alternative 3 ranged from less than the No Action Alternative (up to 18% less under -5,000 cfs) to greater than the No Action Alternative (up to 5% greater under -3,500 cfs) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in Attachment I.7, *ECO-PTM*. The decrease in routing to the Interior Delta could have a large beneficial effect on outmigrating juveniles while the increase in routing could have an adverse effect on outmigrating juveniles.

Summary

Alternative 3 relative to the No Action Alternative using ECO-PTM suggest an adverse or beneficial impact due to differences in flow with a smaller proportion routed to Interior Delta between December and March, particularly under OMR -5,000.

Potential Changes to Through Delta Survival of Spring-run Chinook Salmon

ECO-PTM

For a detailed description of how flows under Alternative 3 may impact spring-run Chinook salmon through-Delta survival, see Alternative 3, Sacramento River Winter-run Chinook Salmon ESU (Section O. 6.8.2).

Mean through-Delta percent survival December through March under Alternative 3 ranged from less than the No Action Alternative (up to 9% less under -3,500 cfs) to greater than the No Action Alternative (up to 16% more under <-2,000 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in Attachment I.7, *ECO-PTM*. The increase in survival under some OMR conditions could have a large beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have a large adverse effect on outmigrating juveniles.

Delta Passage Model

Under Alternative 3, in all water year types, predicted mean survival of spring-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). The change in mean predicted survival to Chipps Island in all water year types is less than or equal to ± .028.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a possible adverse or beneficial impact due to differences in flow on survival of outmigrating juvenile spring-run Chinook salmon, under certain OMR conditions, according to the ECO-PTM model. Under the DPM, the mean predicted survival is only slightly higher.

O.6.10 California Central Valley Steelhead DPS

O.6.10.1 Sacramento River

Spawning and Egg Incubation

Steelhead mostly use the Sacramento River as a migratory corridor for reaching other tributaries to spawn. Data on steelhead spawning in the mainstem Sacramento River is limited and likely restricted to the area upstream of Red Bluff (National Marine Fisheries Service 2009a). No steelhead specific spawner surveys occur in the upper Sacramento River. Data from recent surveys for the four runs of Chinook salmon have found carcasses of O. mykiss but the majority are thought to be resident trout adults (Killam 2022). Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In the Sacramento River, estimated incubation timing based on spawning is December through June.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 3, differences in mean spawning WUA are higher in above normal, below normal, dry, and critically dry water year types, and slightly lower in wet, above normal, and below normal water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 3 and the No Action Alternative is a 0.9% increase in dry water years. The largest reduction in estimated spawning habitat is a -0.05% decrease in wet water year types.

The monthly median value of spawning WUA under Alternative 3 is similar to the No Action Alternative January through April (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are relatively similar in January through March. In April, the median values of spawning WUA are higher across all alternatives when compared to the other spawning months. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently lowest in April when compared to other spawning months (Table O-248). This results in lower spawning WUA results because the steelhead spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 4,000 to 7,000 cfs).

The results of suitable habitat analysis using the SIT LCM habitat models indicated that spawning habitat for steelhead in the upper Sacramento River may increase in April under all alternatives compared to the other spawning months (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). Lack of consistent spawner estimates for steelhead prevented Reclamation staff from calculating spawner limitation ratios for this species.

The results of the two spawning habitat analyses based on CalSim 3 simulated flows suggest that Alternative 3 may have a negligible (less than 1%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. Out of the four months of steelhead spawning, April has the highest estimated spawning WUA across all alternatives.

Redd Dewatering Analysis

The results for Alternative 3 show a substantial reduction in mean redd dewatering potential from wetter to drier water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation reflects flow conditions for the winter and early spring months, when steelhead spawning and incubation occurs. During wet winters and springs, periodic storms and high runoff increase flow fluctuations, which tend to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. Differences in mean redd dewatering potential between Alternative 3 and the No Action Alternative are large, ranging from 17.4% lower under critically dry water year types to 13.0% higher for below normal water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). For individual months, median redd dewatering potential under Alternative 3 is highest in February and lowest in April (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that redd dewatering potential under Alternative 3 relative to the No Action Alternative is higher in some water year types and lower in other water year types, but the overall difference is small.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis* Table 134 for Keswick Dam and Table 136 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 140 for Keswick Dam and Table 142 for RBDD. Full results of the analysis assessing the percent of

months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 170 for Keswick Dam and Table 172 for RBDD.

Results for the three analyses are summarized in Table O-48. Table O-48, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 45.5°F to 55°F successful spawning range analysis, there were nine and zero month-water year type combinations (30.0% and 0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-48). There were zero and one combinations (0% and 3.3%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there were zero and four combinations (0% and 13.3%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. For the 45°F to 52°F range for optimal egg incubation, there were eight and zero combinations (22.9% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were five and one combinations (14.3% and 2.9%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be frequent beneficial water temperature-related effects and some negative effects of Alternative 3 on steelhead spawning and egg incubation in the Sacramento River.

Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on steelhead spawning behavior and redd dewatering from sudden drops in flow. Redd surveys are occurring during the pulse flow period and redd dewatering has not been observed.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead spawning and egg incubation based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are expected to have a minor increase and/or decrease on spawning habitat area and a minor increase and/or decrease for redd dewatering. There may be adverse impacts to spawning behavior from spring pulse flows. There may be redd dewatering following spring pulse flow events, though this has not been observed during redd surveys. Water temperatures above the successful spawning and optimal egg incubation criteria are expected to modestly decrease in frequency and occasionally increase in frequency below Keswick Dam. Water temperatures above the pathogen virulence threshold are expected to also decrease in frequency at RBDD.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in the Sacramento River. The timing of juvenile outmigration depends on the watershed and water year. The rotary screw trap monitoring station at Knight's Landing indicate outmigration into the

Delta, with median passage starting in January and ending in May from 2006-2024 (Columbia Basin Research, University of Washington 2024).

Potential Changes to Steelhead from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 3, mean fry rearing WUA increases in all water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). WUA curves were not developed for steelhead, so the late fall-run Chinook salmon curves were used to quantify spring-run habitat. The largest increase in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 5.6% increase in critically dry water year types. There are no expected reductions in mean fry WUA under Alternative 3 in comparison to the No Action Alternative.

On a monthly scale, the median value of fry rearing WUA under Alternative 3 has a 5% reduction in April in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The median values are similar throughout the other fry rearing months. The estimated fry rearing WUA values under the modeled alternatives are highly variable across the months, April through October, but are generally highest in April and October (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). WUA values of the fry rearing WUA curve are lowest in the range of approximately 7,000 cfs to 13,000 cfs in Segment 5 (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and flows in this range are more frequent during May through August (Table O-248).

The results of the steelhead fry rearing habitat analysis based on CalSim 3 simulated flows suggest that Alternative 3, compared to the No Action Alternative, may have a minor (up to 5.6%) increase in estimated steelhead fry rearing habitat across all water year types. There are some differences in estimated rearing WUA habitat under Alternative 3 when looking at a monthly scale, with a minor (5%) reduction in estimated fry rearing habitat in April in comparison to the No Action Alternative.

Juvenile Rearing Habitat Analyses

Under Alternative 3, mean juvenile rearing WUA increases in wet and above normal water year types and reductions in all other water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The upper and lower limits of the range in WUA values are determined by the ranges of the juvenile rearing WUA curves for late-fall run since there were no reliable WUA curves for steelhead. The analysis includes all months because steelhead juveniles may reside in freshwater for a year or more before emigrating to the ocean. The largest increase in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 1.0% increase in wet water year types. The largest reduction in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 1.6% decrease in critically dry water year types.

On a monthly scale, the median value of juvenile rearing WUA under Alternative 3 is similar to the No Action Alternative most months of the year but constitutes a 7% increase under Alternative 3 in June and a 6% reduction in August (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The estimated juvenile rearing WUA values under the modeled

alternatives are similar December through March, and gradually decrease until the lowest estimated values in July. As discussed previously for spring-run rearing WUA and steelhead spawning WUA, the high WUA values with low variability in the third quartile for December through March result from the peaking of the WUA curve at the lowest flows and frequent low Keswick Dam flow releases during these months to build Shasta Reservoir storage (Table O-248). The wide range of values in the first quartile of these months reflects the high frequency and variability of higher flows in these wet months. The low juvenile rearing WUA values June through August result from releases in the summer months above 10,000 cfs and estimated peak juvenile rearing at flows below 5,000 cfs.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream rearing habitat for juvenile steelhead in the upper Sacramento River may comprise of a 11.4% to -5.5% difference from January through December (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in June and the greatest reduction in estimated habitat may occur in August under Alternative 3 in comparison to the No Action Alternative.

The results of the two steelhead juvenile rearing habitat analyses based on CalSim 3 simulated flows suggest that Alternative 3 compared to the No Action Alternative may have a minor (less than 2%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and the greatest increase in estimated habitat may occur in June (7-11%) in the mainstem upper Sacramento River. August may have the greatest reduction (6%) in estimated juvenile rearing habitat.

Fry Stranding Analysis

The analysis of fry stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Mean stranding of steelhead fry under Alternative 3 shows a consistent reduction from wet water years to critically dry years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Steelhead fry rearing occurs primarily during late winter and spring. Alternative 3 stranding is highest in February, with the median level trending down over the next three months (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher stranding levels for steelhead fry during February and wet water year types likely results because of periodic storms and high runoff that produce increased variability of flow. Mean stranding under Alternative 3 is higher than stranding under No Action Alternative for all water year types except for a 4.3% reduction in dry water years. The increases include 25.0% for above normal water years and 13.5% for below normal years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, mean stranding for steelhead fry is higher under Alternative 3 than under the No Action Alternative, including especially large increases for above normal and below normal water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperature range year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 182 for Keswick Dam and Table 184 for RBDD. Full results of the analysis assessing the percent of months with water temperature above

the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 188 for Keswick Dam, Table 190 for Red Bluff Diversion Dam, and Table 192 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 55°F upper limit of successful smoltification during January through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 196 for Keswick Dam, Table 198 for Red Bluff Diversion Dam, and Table 200 for Hamilton City.

Results for the three analyses are summarized in Table O-49. Table O-49, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 66.2°F upper limit of optimum temperature range, there were zero and one month-water year type combinations (0% and 1.7% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-49). There were no combinations (0%) with unfavorable results at both locations. For the 59.9°F juvenile pathogen virulence threshold, there were one to 11 combinations (1.7% and 18.3%, respectively) with favorable results depending on location. There were zero to three combinations (0% to 5.0%) with unfavorable results depending on location. For the 55°F upper limit of successful smoltification, there were zero to eight combinations (0% to 32.0%) with favorable results depending on location. There were zero to one combination (0% to 4%) with unfavorable results depending on location. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 3 on steelhead juvenile rearing and emigration in the Sacramento River.

<u>Sacramento River Pulse Flows</u>

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

<u>Summary</u>

There are expected moderate adverse and moderate beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are expected to have a minor increase and/or decrease on fry and juvenile rearing habitat area. Changes in flows are expected to increase fry stranding during above normal/below normal water year types and cause minor decreases in fry stranding during dry water year types. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. Water temperatures above the smoltification criteria are expected to have a decrease in frequency below Keswick Dam. Water temperatures above the pathogens and disease criteria are expected to decrease in frequency at RBDD and have a minor increase in frequency at Hamilton City under Alternative 3 compared to the No Action Alternative.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). Historical data at the Fremont Weir have shown that adult steelhead migrate upstream in the Sacramento River during most months of the year, beginning in July, peaking in September, and continuing through March (Hallock 1989; McEwan 2001; Hallock et al. 1957).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

A flow threshold of 3,250 cfs has been used to evaluate the potential for adverse effects on steelhead migrating and holding adults in the Sacramento River (Long-term Operations 2019 EIS). Flows in the Sacramento River rarely drop below this level, and adults have not been observed to experience passage delays, crowding, or other adverse effects at this flow. Therefore, it represents a reasonable threshold for evaluating the potential for adverse effects on migrating and holding adults.

During the steelhead adult upstream migration and holding period, CalSim 3 modeling of Sacramento River mean monthly flows at Wilkins Slough indicate that flows may go below the minimum flow in September of critically dry water years but flows are expected to have a minor (3%) increase under Alternative 3 in comparison to the No Action Alternative (Table O-250). Flows in the Sacramento River at Wilkins Slough range from 3,250 cfs in September of critically dry water years to 19,972 cfs in February of wet water years during the adult migration period. Flows in the Sacramento River at RBDD range from about 5,090 cfs in September of critically dry water years to 37,391 cfs in February of wet water years during the adult migration period (Table O-249). Under Alternative 3, Reclamation will operate minimum instream flows at 2,300 cfs in March, July, and August, and 3,250 cfs from September through February but the schedule may change in critically dry water years (WRO Order 90-5). Since peak adult migration occurs around September, there may be minor beneficial effects to adult steelhead in September of critically dry years if flows are reduced in the lower Sacramento River under Alternative 3.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range for minimal migration impairment during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 110 for Keswick Dam, Table 112 for Red Bluff Diversion Dam, and Table 114 for Hamilton City. Results for the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 118 for Keswick Dam, Table 120 for Red Bluff Diversion Dam, and Table 122 for Hamilton City. Results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for adult migration and holding during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 126 at Keswick Dam, Table 128 for Red Bluff Diversion Dam, and Table 130 for Hamilton City.

Results for the three analyses are summarized in Table O-50. Table O-50, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 41°F to 66.2°F range for minimal migration impairment, there were zero to three month-water year type combinations (0% to 6.7% of total combinations during the period) with favorable results depending on location (Table O-50). There were no combinations (0%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at any location. There were no combinations (0%) with unfavorable results depending on location. For the 59.9°F adult migration pathogen virulence threshold, there were zero to six combinations (0% to 13.3%) with favorable results depending on location. There were zero to two combinations (0% to 4.4%) with unfavorable results depending on location. These results suggest that there would be positive effects and negligible negative effects of Alternative 3 on steelhead adult upstream migration and holding.

Sacramento River Pulse Flows

There may be beneficial impacts of spring pulse flows on adult migration through decreased travel time.

Summary

There are expected minor beneficial impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 3 compared to the No Action Alternative. Under Alternative 3, changes in flows are expected to have a negligible impact in the upper portions of the Sacramento River but may have a minor beneficial impact during peak migration in September of critically dry water year types, in the lower Sacramento River below Wilkins Slough. Spring pulse flow events may decrease travel time for adult migrants. Water temperatures above the pathogens and disease criteria decrease in frequency in the lower Sacramento River at RBDD and below Keswick Dam under Alternative 3. Water temperatures above the pathogens and disease criteria are expected to have negligible increases in frequency in the lower Sacramento River at Hamilton City. Water temperatures outside the optimal migration range also decrease in frequency in the lower Sacramento River at Hamilton City under Alternative 3.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Similar to the section above for adult migration, a threshold of 3,250 cfs has been used to evaluate the potential for adverse effects (Long-term Operations 2019 EIS). Flows in the Sacramento River rarely drop below this level, and adults have not been observed to experience passage delays, crowding, or other adverse effects at this flow. Therefore, it represents a reasonable threshold for evaluating the potential for adverse effects on migrating and holding adults.

During the steelhead kelt emigration period, approximately February through June, CalSim 3 modeling of Sacramento River mean monthly flows do not go below the threshold of 3,250 cfs at Keswick Dam, RBDD, Wilkins Slough or Hamilton City under Alternative 3 and the No Action Alternative (Table O-248 through Table O-251). These results suggest flows are adequate for kelt emigration in the Sacramento River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F migration impairment limit during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 146 for Keswick Dam, Table 148 for Red Bluff Diversion Dam, and Table 150 for Hamilton City. Full results for the percent of months with water temperature above the 69.8°F lethal limit to kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 154 for Keswick Dam, Table 156 for Red Bluff Diversion Dam, and Table 158 for Hamilton City. Full results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 162 for Keswick Dam, Table 164 for Red Bluff Diversion Dam, Table 166 for Hamilton City.

Results for the three analyses are summarized in Table O-51. Table O-51, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 66.2°F migration impairment limit, there were zero to one month-water year type combinations (0% to 4.0% of total combinations during the period) with favorable results depending on location (Table O-51). There were zero to two combinations (0% to 8.0%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at all locations. There were no combinations (0%) with unfavorable results depending at all locations. For the 59.9°F adult migration pathogen virulence threshold, there were zero to five combinations (0% to 20.0%) with favorable results depending on location. There were zero to two combinations (0% to 8.0%) with unfavorable results depending on location. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 3 on steelhead kelt emigration in the Sacramento River.

Sacramento River Pulse Flows

There may be beneficial impacts of spring pulse flows on kelt emigration through decreased travel time.

Summary

There are expected minor beneficial impacts of seasonal operations on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are expected to be above the minimum flow to avoid crowding and passage delays from Keswick Dam to Hamilton City in the Sacramento River. Spring pulse flow events may decrease travel time for kelt emigration. Water temperatures above the pathogens and disease criteria may slightly decrease in frequency at RBDD. Water temperatures above the migration impairment limit may slightly increase in frequency at Hamilton City.

O.6.10.2 Clear Creek

Spawning and Egg Incubation

In Clear Creek, the temporal distribution of redd count data shows spawning December through April, with peak spawning January (Schaefer et al. 2019; Provins and Chamberlain 2019a, 2019b, 2020). Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In Clear Creek, estimated incubation timing based on spawning is late-December through late-May.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 3, mean spawning WUA increases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The greatest increase in estimated spawning habitat is an 7.4% increase in dry water year types under Alternative 3 in comparison to the No Action Alternative. There are no anticipated reductions in mean spawning WUA under Alternative 3 in comparison to the No Action Alternative.

The mean values of spawning WUA by month are higher under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). All spawning months (December through March) are expected to have similar WUA values under Alternative 3.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that steelhead spawning habitat under Alternative 3 may have a minor decrease (0.5-1.9%) in January and March, and a minor increase (3.4%) in February in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The two spawning habitat analyses based on CalSim 3 simulated flows suggest that Alternative 3 may have a minor to moderate beneficial effect (up to 7.4% increase) in steelhead spawning habitat in Clear Creek across all water year types when compared to the No Action Alternative.

The SIT LCM indicates that spawning habitat will likely have a minor decrease in January/March and minor increase in February on a monthly scale in Clear Creek but the other WUA analyses did not see this trend.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis* Table 138 for Clear Creek at Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 144 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 174 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-52. Table O-52, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 45°F to 55°F range for successful spawning, there was one month-water year type combinations (3.3% of total combinations during the period) with both favorable and unfavorable results below Whiskeytown Dam (Table O-52). For the 59.9°F adult pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 45°F to 52°F range for optimal egg incubation, there was one combination (2.9%) with favorable results and three combinations (8.6%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on steelhead spawning and egg incubation in Clear Creek.

Summary

There are expected beneficial impacts of seasonal operations on steelhead spawning and egg incubation based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows may have a beneficial impact on spawning habitat area across all water year types. Water temperatures outside of the optimal egg incubation range are expected to have negligible increases in frequency overall in Clear Creek below Whiskeytown Dam.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in Clear Creek. The timing of juvenile outmigration depends on the watershed and water year. The rotary screw trap monitoring station in lower Clear Creek indicates outmigration into the Sacramento River with median passage starting in November and ending in June, with peak passage between April and June (Schraml and Chamberlain 2019a, 2019b, 2020, 2021).

Potential Changes to Steelhead from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 3, mean fry rearing WUA decreases in wet water year types and increases in all other water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 1.1% increase in dry water year types. The only decrease in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 0.03% decrease in wet water year types.

The mean values of fry rearing WUA by month are similar under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). All fry rearing months (February through June) are expected to have similar WUA values under Alternative 3.

The results of the fry rearing habitat analysis based on CalSim 3 simulated flows suggest that Alternative 3 may have a negligible (less than 1.2%) increase and/or decrease in estimated steelhead fry rearing habitat across all water year types in Clear Creek.

Juvenile Rearing Habitat Analyses

Under Alternative 3, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 3 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is an 6.5% decrease in dry water year types. On average across all water year types, there is a 6% reduction in estimated juvenile rearing habitat under Alternative 3.

The mean values of juvenile rearing WUA by month are lower July through October and higher in November and December under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the period analyzed, December is expected to have the highest juvenile rearing WUA values under Alternative 3.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for steelhead in Clear Creek may decrease 0.3-20.3% in February and June through October and may increase 4.1-14.2% November through January and March through May under Alternative 3 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest decrease in estimated juvenile rearing habitat may occur in August and the greatest increase in juvenile rearing habitat may occur in May.

The results of the two steelhead juvenile rearing habitat analyses suggest that Alternative 3 may have an adverse effect, as rearing habitat may decrease on average by 6% across all water year types in comparison to the No Action Alternative, and may increase and decrease throughout the year on a monthly scale. The steelhead juvenile rearing WUA analysis in Attachment O.1, *Clear Creek Weighted Usable Area Analysis* analyzed the period between July and December, but some juveniles may rear year-round in Clear Creek, up to four years before emigration to the ocean.

The greatest decrease in estimated juvenile rearing habitat may occur in August and the greatest increase in juvenile rearing habitat may occur in May.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperature range year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 186 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 194 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 55°F upper limit of successful smoltification during January through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 202 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-53. Table O-53, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 66.2°F upper limit of optimum temperature range for juvenile steelhead growth, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-53). For the 59.9°F juvenile pathogen virulence threshold, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 55°F upper limit of successful smoltification, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on juvenile steelhead rearing and emigration in Clear Creek.

Summary

There are expected adverse impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are expected to have a decrease in juvenile rearing habitat area across all water year types. Water temperatures above the three juvenile temperature criteria are not anticipated to change in frequency in Clear Creek below Whiskeytown Dam under Alternative 3.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). In Clear Creek, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as August and throughout February (Killam 2022).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the period of adult steelhead migration and holding in Clear Creek, the mean monthly flows under Alternative 3 compared to the No Action Alternative are on average reduced August through October and increased November through January (Table O-257). Throughout the full simulation period, flows on average will range from 17-33% reduction under Alternative 3. Flows are expected to generally be above 100 cfs throughout this period in Clear Creek, and unlikely to cause delays in migration and crowding for adult steelhead.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range for minimal migration impairment during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 116 for below Whiskeytown Dam. Results for the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 124 for below Whiskeytown Dam. Results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for adult migration and holding during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 32 for below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-54. Table O-54, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 41°F to 66.2°F range for minimal migration impairment, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-54). For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F pathogen virulence threshold for adult m, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on steelhead adult upstream migration and holding in Clear Creek.

Summary

There are expected negligible impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 3 in comparison with the No Action Alternative. Under Alternative 3 compared to the No Action Alternative, Clear Creek flows are likely adequate for migrating adults. Water temperatures above the three adult temperature criteria are not anticipated to change in frequency in Clear Creek below Whiskeytown Dam under Alternative 3.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the period of steelhead kelt emigration in Clear Creek, the mean monthly flows under Alternative 3 compared to the No Action Alternative will be reduced towards the tail ends of emigration and increased during peak emigration (Table O-257). Throughout the full simulation period, flows on average will have a 6% reduction in February and a 28% reduction in June under Alternative 3. Throughout the full simulation period, flows on average will have a 20-41% increase March through May under Alternative 3. Flows are above 100 cfs in Clear Creek throughout this period under Alternative 3. These results suggest there are negligible effects of flow to steelhead kelt emigration under Alternative 3.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F migration impairment limit during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 152 for below Whiskeytown Dam. Full results for the percent of months with water temperature above the 69.8°F lethal limit to kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 160 for below Whiskeytown Dam. Full results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 168 for below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-55. Table O-55, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 66.2°F kelt migration impairment limit, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-55). For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F pathogen virulence threshold for adult migration, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on steelhead kelt migration in Clear Creek.

Summary

There are expected negligible impacts of seasonal operations on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 3 in comparison with the No Action Alternative. Under Alternative 3, flows are likely adequate for the small proportion of the population that emgirate as kelts in Clear Creek. Water temperatures above the three temperature criteria for kelts are not anticipated to change in frequency in Clear Creek below Whiskeytown Dam under Alternative 3 in comparison to the No Action Alternative

O.6.10.3 Lower American River

Spawning and Egg Incubation

In the lower American River, redd surveys have reported spawning January through mid-April, with peak spawning in February (Sweeney et al. 2021). The median months of spawning from 2002-2021 were from January through March. Redd surveys on the lower American River do not occur until the first week of January, and there are reports from the Sacramento Water Forum (2015) that indicate spawning starts in late December. Therefore, the timing window of spawning on the American River was analyzed from late December until March.

Steelhead egg incubation varies with water temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). On the lower American River, egg incubation starts in late December and ends in late May, with peak incubation between February and April (Hannon pers. comm. 2023; Sacramento Water Forum 2015).

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 3, lower American River steelhead mean spawning WUA under Alternative 3 is highest in critically dry water years and falls sharply with wetter water year types (Attachment M.3, *American River Weighted Usable Area Analysis*). This pattern of variation occurs because streamflows during the January through March spawning season of steelhead rise from dry to wetter water year types (Table O-259). The lower American River steelhead spawning WUA curve peaks at about 2,000 cfs (Attachment M.3, *American River Weighted Usable Area Analysis*) and flows under Alternative 3 are consistently well above this level in the wetter water years. February flows are especially high in all but critically dry water years and consequently February shows the lowest median spawning WUA for all alternatives (Attachment M.3, *American River Weighted Usable Area Analysis*). Differences in mean spawning WUA between Alternative 3 and the No Action Alternative are small, ranging from 2.7% lower under Alternative 3 for wet and above normal water years to 1.4% higher for critically dry water years (Attachment M.3, *American River Weighted Usable Area Analysis*). Median spawning WUA is higher under Alternative 3 than the No Action Alternative for January, is slightly lower for February, and is about the same for March (Attachment M.3, *American River Weighted Usable Area Analysis*).

The results of the SIT LCM model for Alternative 3 are generally the same as those described above, showing little difference in spawning WUA in comparison to the results for the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The SIT analysis results include a 9.1% reduction for Alternative 3 in April, but April was not included for the spawning WUA analysis above.

Overall, the results indicate that there is little difference in mean spawning WUA for steelhead between Alternative 3 and the No Action Alternative.

Redd Dewatering Analysis

The results of the analysis for redd dewatering potential for lower American River steelhead indicate that redd dewatering is much greater in wetter water years than in drier water years for Alternative 3 (Attachment M.1, *American River Redd Dewatering Analysis*). This difference reflects the greater frequency of larger flow fluctuations in wetter years. Mean steelhead redd dewatering potential is lower under Alternative 3 than under the No Action Alternative for all water year types except dry water years, which shows an 11.7% increase. Most of the reductions are large, including 34.1% lower in below normal water years, 21.9% lower in critically dry water years, and 13.5% lower in above normal water years (Attachment M.1, *American River Redd Dewatering Analysis*). In absolute terms, the large relative change for below normal water years results from an absolute change of reduction from 20.6% to 13.6%, which is still large. For the individual months of steelhead spawning in the lower American River, median redd dewatering potential is highest and variability is greatest in February for both the No Action Alternative and Alternative 3 (Attachment M.1, *American River Redd Dewatering Analysis*). The occurs because flows during the two-month incubation period following February spawning exhibit greater declines than those for January and March (Table O-259).

Overall, the results indicate that Alternative 3 produces substantial reductions in redd dewatering potential of steelhead relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 20 for Hazel Avenue and Table 22 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold for spawning adults during December through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 24 for Hazel Avenue and Table 26 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 40 for Hazel Avenue and Table 42 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold during December through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 44 for Hazel Avenue and Table 46 for Watt Avenue.

Results for the analysis are summarized in Table O-56. Table O-56 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 45°F to 55°F range for successful spawning there were zero and one month-water type combinations (0% and 5%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-56). There were zero and one month-water type combination (0% and 5%, respectively) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively. For the 59.9°F spawning pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both Hazel Avenue and Watt Avenue. For the 45°F to 52°F range for optimal egg incubation there were there were one to two month-water type combinations (3.3% and 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were four and one month-water type combinations (13.3% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold, there were one and two month-water type combinations (3.3% to 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water type combinations (6.7% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that Alternative 3 would have positive (3.3% - 6.7% favorable) and negative (3.3% - 13.3% unfavorable) water temperature-related effects to steelhead spawning and egg incubation in the lower American River.

Summary

There are expected minor adverse and substantial beneficial impacts of seasonal operations on steelhead spawning and egg incubation in the lower American River based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows may have a minor increase and/or decrease on spawning habitat area but may substantially decrease redd dewatering potential. Water temperatures above the optimal range for egg incubation are expected to increase in frequency (6.7% favorable, 13.3% unfavorable) in the lower American River at Hazel Ave.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Yearling rearing is year-round in the lower American River. Young of the year fry rearing is from February through May (Sacramento Water Forum 2015). The timing of juvenile outmigration depends on the watershed and water year. The rotary screw trap monitoring station in the lower American River indicates outmigration into the Sacramento River with median passage starting in January and ending in May, with peak passage between March and May (Day 2022a).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the period of steelhead rearing in the lower American River, the mean monthly flows under Alternative 3 compared to the No Action Alternative are increased and decreased depending on the month under critically dry water year types, which may alter their rearing habitat (Table O-260, Table O-259). Reductions under Alternative 3 are anticipated in October and November of critically dry years when flows are below 1,000 cfs, potentially impacting juvenile (yearling) habitat. The greatest increase in flows under Alternative 3 occur in April of a critically dry water year type (37% in the lower American River at H St) which may benefit young of the year steelhead fry rearing. Flows are expected to be either similar or increase during their other fry rearing months under Alternative 3. The greatest reduction occurs in June of a below normal water year type (43% in the lower American River at H St).

The CalSim 3 simulated flow results suggest that changes in flow in the lower American River under Alternative 3 compared to the No Action Alternative may have a minor adverse and a minor beneficial effect on juvenile habitat, and a minor beneficial effect for fry rearing during critically dry water year types. There are no reliable estimates for steelhead juvenile rearing habitat using weighted usable area analyses. USFWS 1985 derives spawning and rearing weighted usable area on fall-run Chinook salmon, but this study did not assess steelhead and has not been peer reviewed.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 48 for Hazel Avenue and Table 50 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F rearing and outmigration pathogen virulence threshold year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 52 for Hazel Avenue and Table 54 for Watt Avenue. Full results of the analysis assessing water temperatures above the percent of months with water temperature above the 55°F limit of successful smoltification during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 56 for Hazel Avenue and Table 58 for Watt Avenue.

Results for the three analyses are summarized in Table O-57. Table O-57 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels, there were one and two month-water combinations (1.7 and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-57). There were three and six month-water combinations (5.0% and 10%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F juvenile rearing and outmigration pathogen virulence threshold, there was one and three month-water combinations (1.7% and 5.0%, respectively) with favorable results at Hazel Avenue

and Watt Avenue, respectively. There were six and one month-water combinations (10% and 1.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 55°F limit of successful smoltification, there were zero and one month-water combinations (0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue. There were zero month-water combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be positive (1.7% - 5% favorable) and negative (1.7% - 10% unfavorable) water temperature-related effects to steelhead juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration in the lower American River based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3 in critically dry water years, reductions in flows may decrease rearing habitat area (June, October, and November) and increases in flows may increase rearing habitat area (December, March, and April). Water temperatures above the optimum juvenile growth criteria have increases in frequency at Watt Avenue. Water temperatures above pathogens and disease criteria have increases in frequency at Hazel Avenue.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). In the lower American River, adult steelhead migration may occur as early as July and through early April, with peak abundance in January and February (Sacramento Water Forum 2015; Hallock 1989; Hallock et al. 1957).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Flows in the lower American River below Nimbus Dam are expected to be similar during peak adult migration and holding under Alternative 3 compared to the No Action Alternative (Table O-259 and Table O-260). Peak steelhead adult migration in the lower American River occurs between January and February (Sacramento Water Forum 2015), when flows are expected to be less than a 9% increase or decrease under Alternative 3 across all water year types (Table O-259 and Table O-260). The largest reductions in flow under Alternative 3 for peak adult migration occur in January of critically dry water year types, but flows are expected to be above 1,000 cfs during this period. The largest increases in flow under Alternative 3 throughout the migration period occur in March and April of all water year types. Throughout the adult migration period, November has the greatest reductions in flow under Alternative 3, with a 31% reduction in critically dry water year types. Flows in October and November of critically water year types are expected to be below 1,000 cfs under Alternative 3 but are likely still adequate for adult migration (Table O-260).

These results of the CalSim 3 simulated flows suggest that there may be a negligible effect of Alternative 3 compared to the No Action Alternative on steelhead adult migration and holding in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range of minimal migration impairment for adult steelhead during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 8 for Hazel Avenue and Table 10 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 12 for Hazel Avenue and Table 14 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult upstream migration and holding pathogen virulence threshold during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 16 for Hazel Avenue and Table 18 for Watt Avenue.

Results for the three analyses are summarized in Table O-58. Table O-58 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 41°F to 66.2°F range of minimal migration impairment for adult steelhead under Alternative 3, there were five and zero month-water combinations (10% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue (Table O-58). There were one to four month-water combinations (2.0% and 8.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there were three and two month-water combinations (6.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two to four month-water combinations (4.0% and 8.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F adult upstream migration and holding pathogen virulence threshold, there were zero and one month-water combinations (0.0% and 2.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and five month-water combinations (4.0% and 10.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be positive (4% - 6% favorable) and negative (2% - 8% unfavorable) water temperature-related effects to steelhead adult upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There are expected negligible impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 3 in comparison with the No Action Alternative. Under Alternative 3 compared to the No Action Alternative, there are likely adequate flows during peak adult migration and holding. Water temperatures above all three temperature criteria both increase in frequency and decrease in frequency (2-6%) in the lower American River under Alternative 3 in comparison to the No Action Alternative, depending on the location (Hazel Ave or Watt Ave).

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Flows in the lower American River below Nimbus Dam are expected to be similar to or increased during peak kelt emigration under Alternative 3 compared to the No Action Alternative (Table O-259 and Table O-260). The largest reductions in flow under Alternative 3 during kelt emigration occur in June of below normal water year types, but flows are expected to be above 1,000 cfs during this period across all water year types. The largest increases in flow under Alternative 3 occur in March and April of all water year types, but flows are likely adequate for kelt emigration throughout the period.

These results of the CalSim 3 simulated flows suggest that there may be a negligible effect of Alternative 3 compared to the No Action Alternative on steelhead kelt emigration in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F limit of migration impairment for steelhead kelt emigration during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 28 for Hazel Avenue and Table 30 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F lethal limit for steelhead kelt emigration during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 32 for Hazel Avenue and Table 34 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F kelt emigration pathogen virulence threshold during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 36 for Hazel Avenue and Table 38 for Watt Avenue.

Results for the three analyses are summarized in Table O-59. Table O-59 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3, for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead, there were one and zero month-water combinations (4.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-59). There were zero and four month-water combinations (0.0% and 16%, respectively) with unfavorable results

at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there were zero month-water combinations (0%) with favorable results at Hazel Avenue and Watt Avenue. There were zero and four month-water combinations (0.0% and 16.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F kelt emigration pathogen virulence threshold, there were one and two month-water combinations (4.0% and 8.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue. There were three and zero month-water combinations (12.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that there would be positive (4% - 8% favorable) and negative (12% - 16% unfavorable) water temperature-related effects to steelhead kelt emigration in the lower American River at Hazel Avenue and Watt Avenue. Negative effects are expected to be greater in magnitude than positive effects.

Summary

There are expected minor to moderate adverse and minor beneficial impacts of seasonal operations on steelhead kelt emigration based on analyses of simulated flows and water temperature under Alternative 3 in comparison with the No Action Alternative. Under Alternative 3 compared to the No Action Alternative, there are likely adequate flows for kelt emigration. Water temperatures above the three temperature criteria both increase in frequency (4-16%) and decrease in frequency (4-8%) in the lower American River under Alternative 3 in comparison to the No Action Alternative, depending on the location (Hazel or Watt Avenue).

O.6.10.4 Bay-Delta

Juvenile Rearing and Emigration

While juvenile steelhead can be found in all waterways of the Delta, they are seen more frequently in the main channels to their natal river systems (National Marine Fisheries Service 2009a). The San Francisco Estuary is used as a short-term outmigration corridor for juvenile steelhead but the propensity of rearing in the Delta is currently unknown (Hayes and Kocik 2014, Chapman et al. 2015, Buchanan et al. 2021). The USFWS monitoring programs (Sacramento beach seines, Sacramento trawl, and Knight's Landing RST) indicate outmigration timing from the Sacramento River with first median passage in January and last median passage in May (Columbia Basin Research, University of Washington 2024). Outmigration from the San Joaquin River is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024).

Potential Changes to Steelhead from Seasonal Operations

Zone of Influence

Differences in hydrology under Alternative 3 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. With incremental decreases in OMR under Alternative 3 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under Alternative 3 may impact the proportional overlap at Turner Cut, San Joaquin

River at Jersey Point, and Old River at Middle River, see Alternative 3, Sacramento River Winter-run Chinook Salmon ESU (Section O.6.8.2, *Zone of Influence*).

Flow into Junctions

For a full description of Flow into Junctions model background, see Section O.4.8.2, *Sacramento River Winter-run Chinook Salmon ESU, Juvenile Rearing and Emigration in the Bay-Delta*. The following section covers discussion of the Central Valley Project and Head of Old River junctions. An expanded set of junction analysis results can be found in Attachment I.10, *Flow into Junctions*.

Under Alternative 3 in the -2,000 and -3,500 OMR bins, predicted proportion of flow entering the Central Valley Project (CVP) is greater than the No Action Alternative, and less than the No Action Alternative in the -5,000 and <-5,500 OMR bins. Changes in predicted proportion of flow entering the CVP when OMR was -2,000, -3,500, and -5,000 were less than ± 0.0406, indicating a negligible difference from the No Action Alternative. However, when OMR was <-5,500 the change in flow into CVP was -0.0933, indicating that slightly less flow will be routed into CVP under Alternative 3 than when compared to the No Action Alternative.

Under Alternative 3 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the Head of Old River (HOR) is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.0404, indicating a negligible difference between Alternative 3 and the No Action Alternative.

Summary

Alternative 3 relative to the No Action is expected to influence flow into the Head of Old River and CVP junctions. Under Alternative 3, no change to possibly less flow into CVP under OMR -3,500; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 3 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Steelhead

Salvage Density and Negative Binomial

Predictions from the salvage density and the negative binomial model for steelhead include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of steelhead at SWP Banks Pumping Plant for all the months December through April and all water years Alternative 3 was lower than predicted average monthly loss under the No Action Alternative, with up to a 49% decrease in predicted loss for dry water year types (Table O-60). Predicted average monthly loss of steelhead at CVP Jones Pumping Plant for all the months October through April for Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for all water year types, with up to a 58% decrease in predicted loss for dry water year types (Table O-61). For detailed

information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly salvage of juvenile steelhead at the Delta fish collection facilities for the months of December through June under Alternative 3 was lower than predicted loss under the No Action Alternative for all water year types except for above normal water year types which had a 3% increase in predicted loss. For all other water year types, predicted loss of steelhead at Jones was lower, with a reduction of up to 67% for wet water year types for Alternative 3 as compared to the No Action Alternative (Table O-62). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*, Table 8.

Summary

The results of the two entrainment models suggest diminished impacts of exports under Alternative 3 compared to the No Action Alternative, with substantial decreases in entrainment. Alternative 3 relative to the No Action Alternative is expected to have a moderate to substantial decreases (14-67%) in steelhead loss in wet, below normal, dry, and critically dry water year types in the Delta at both fish facilities under the Negative Binomial model. There is an expected increase (3%) in steelhead loss in above normal water year types under the Negative Binomial model. Alternative 3 relative to the No Action Alternative is expected to have moderate to substantial decreases (15-58%) in steelhead loss across all water year types in the Delta at both fish facilities under the Salvage Density model.

Potential Changes to Routing and Through Delta Survival of Steelhead

ECO-PTM

. For a detailed description of how flows under Alternative 3 may impact steelhead routing, see Alternative 3, Sacramento River Winter-run Chinook Salmon ESU (Section O. 6.8.2).

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under Alternative 3 ranged from less than the No Action Alternative (up to 18% less under -5,000 cfs) to greater than the No Action Alternative (up to 5% greater under -3,500 cfs) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in Attachment I.7, *ECO-PTM*. The decrease in routing to the Interior Delta could have a large beneficial effect on outmigrating juveniles while the increase in routing could have an adverse effect on outmigrating juveniles.

Mean through-Delta percent survival December through March under Alternative 3 ranged from less than the No Action Alternative (up to 9% less under -3,500 cfs) to greater than the No Action Alternative (up to 16% more under <-2,000 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in Attachment I.7, *ECO-PTM*. The increase in survival under some OMR conditions could have a large beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have a large adverse effect on outmigrating juveniles.

Summary

Alternative 3 relative to the No Action Alternative using ECO-PTM suggest an adverse or beneficial impact due to differences in flow, with a smaller proportion routed to Interior Delta between December and March, particularly under OMR -5,000. Alternative 3 relative to the No Action Alternative is expected to have a possible adverse or beneficial impact due to differences in flow on survival of outmigrating juvenile steelhead, under certain OMR conditions, according to the model.

O.6.10.5 San Joaquin River

Juvenile Emigration

The San Joaquin River is primarily documented as an outmigration corridor for juvenile steelhead (Buchanan et al. 2021). Outmigration from the San Joaquin River into the Delta is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024). RSTs in the lower Stanislaus River, a tributary to the San Joaquin River, suggests juvenile emigration into the San Joan Joaquin River starts in January and ends in June (Day 2022b).

Potential Changes to Steelhead from Seasonal Operations

Changes in flows from seasonal operations under Alternative 3 compared to the No Action Alternative may have a negligible effect on juvenile steelhead in the San Joaquin River. During the evaluated months in the juvenile emigration period, CalSim 3 estimates of mean monthly flows at Vernalis would generally be similar or decreased under Alternative 3 compared to the No Action Alternative across all water year types (Table O-263). Throughout the full simulation period, average flows will range from 3,364 to 6,507 cfs under Alternative 3 during juvenile emigration.

Changes in water temperature from seasonal operations Alternative 3 compared to the No Action Alternative are likely to have a negligible effect on juvenile steelhead in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile emigration period (Figure O-15).

Summary

The results of these two simulation models indicate there are expected negligible impacts of seasonal operations on juvenile steelhead in the San Joaquin River under Alternative 3 in comparison with the No Action Alternative.

Adult Upstream Migration and Holding

Steelhead/rainbow trout of anadromous parentage occur at low numbers in all three major San Joaquin River tributaries. These tributaries have a higher percentage of resident rainbow trout compared to the Sacramento River and its tributaries (Zimmerman et al. 2009). Estimates of migrating adults in the San Joaquin River are made from the CDFW angler report cards and suggest that migration starts in July, peaks in December and January, and ends in March (California Department of Fish and Wildlife 2007).

Potential Changes to Steelhead from Seasonal Operations

Changes in flows from seasonal operations under Alternative 3 compared to the No Action Alternative may have a minor adverse effect on adult steelhead migration and holding in the San Joaquin River in critically dry water year types. During the evaluated months in the adult migration period, CalSim 3 estimates of mean monthly flows at Vernalis would decrease from July through March of critically dry water year types under Alternative 3 compared to the No Action Alternative (Table O-263). Throughout the full simulation period, average flows will range from 466 to 2,065 cfs under Alternative 3.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible effect on adult steelhead migration and holding in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the adult migration period (Figure O-15).

Summary

There are likely negligible to minor adverse impacts of seasonal operations on adult steelhead migration and holding in the San Joaquin River based on analyses of simulated flows and water temperature under Alternative 3 in comparison with the No Action Alternative.

O.6.10.6 Stanislaus River

Spawning and Egg Incubation

Data on steelhead spawning in the Stanislaus River is limited, but adults appear to spawn primarily from January to April. In 2021, as part of the reasonable and prudent measure to accelerate steelhead monitoring and research in the NMFS (2019) Biological Opinion, CDFW initiated the Stanislaus River Life Cycle Monitoring Program. Based on the initial redd survey report, which had a late start due to COVID-19 restrictions, spawning appears to start in February and last until April (Kok and Keller 2023). Although few steelhead spawning surveys have been conducted in the Stanislaus River, spawning *O. mykiss* has been documented upstream of the Highway 120 Bridge in Oakdale, between Goodwin Dam and the Oakdale Recreation Area.

Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional 2-4 weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In the Stanislaus River, timing can only be estimated and would be January through late May.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

The spawning WUA results for Alternative 3 show a different pattern of variation in mean spawning WUA with water year type from the No Action Alternative and all the other alternatives (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the No Action Alternative and the other alternatives, the mean spawning WUA consistently increases from wet to critically dry water years, but for Alternative 3 mean spawning WUA is higher for above

normal water years than for below normal water years. The mean spawning WUA estimates for Alternative 3 are about the same or well below those for the No Action Alternative, depending on the water year type, including reductions of 24.0%, 21.5%, and 18.5% for wet, dry, and below normal water years, respectively (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The spawning WUA results for individual months show much lower median spawning WUA under Alternative 3 relative to the No Action Alternative in December through March and higher median spawning WUA in April (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results of the SIT LCM model for Alternative 3 are generally consistent with those described above for spawning WUA, showing substantial reductions in spawning habitat in comparison to the results for the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

Overall, the results indicate that mean spawning WUA for steelhead is lower under Alternative 3 than under the No Action Alternative, including much lower in wet, dry, and below normal water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 16 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold for spawning adults during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 18 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 32 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 54°F index value for egg incubation during December through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis,* Table 34 Full results of the analysis assessing the 59.9°F fry pathogen virulence threshold during December through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 36 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-63. Table O-63 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 45°F to 55°F range for successful spawning under Alternative 3, there were three month-water year type combinations (10.0%) with favorable results and zero month-water year type combination (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-63). For the 59.9°F spawning pathogen virulence threshold, there were zero month-water year type combinations (0%) with favorable and unfavorable results at Orange Blossom Bridge. For the 45°F to 52°F range for optimal egg incubation analysis, there were four month-water year type combination (10.0%) with favorable results and two month-water year type combinations (5.0%) with unfavorable results at Orange Blossom Bridge. For the 59.9°F fry pathogen virulence

threshold analysis, there was one month-water year type combinations (2.5%) with favorable results and zero month-water year type combinations (0%) with unfavorable results at Orange Blossom Bridge.

These results suggest that Alternative 3 would have beneficial effects on steelhead spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

There are expected adverse impacts of seasonal operations on steelhead spawning and egg incubation in the Stanislaus River based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are expected to have a decrease in spawning habitat area, particularly in wet, dry and below normal water year types. Water temperatures outside the successful spawning range and egg incubation range are expected to decrease in frequency the Stanislaus River at Orange Blossom Bridge.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in the Stanislaus River. The timing of juvenile outmigration depends on the watershed and water year. Rotary screw traps in the lower Stanislaus River suggests juvenile emigration into the San Joan Joaquin River starts in January and ends in June (Day 2022b).

Potential Changes to Steelhead from Seasonal Operations

Rearing Habitat—WUA Analyses

The results for mean fry rearing WUA under Alternative 3 show consistent reductions from drier to wetter water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the steelhead fry WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show moderately reduced WUA with increased flow, especially in the Orange Blossom Bridge and Riverbank reaches, which are the longest segments. Mean fry rearing WUA under Alternative 3 is lower to that for the No Action Alternative in all water year types except wet years, for which mean WUA is 1.0% higher under Alternative 3, but all differences are small. The largest reduction is 3.4% for dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fry rearing period, median rearing WUA is lower under Alternative 3 than under the No Action Alternative in April and May and the medians are similar in March and June (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results for juvenile rearing WUA under Alternative 3 show a minor increase in mean rearing WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in juvenile rearing WUA between Alternative 3 and the No Action Alternative are small, ranging from 0.3% lower for above normal water years to 1.7% higher for dry water years. Juveniles rear year-round and juvenile rearing WUA is highest in April and May (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For most months, median juvenile rearing WUA is similar between Alternative 3 and the No Action Alternative, but for February and March, the Alternative 3 medians are much higher.

The SIT LCM model provides rearing habitat results for all juveniles, not separating out the fry stage from older juveniles. The instream juvenile rearing habitat results for Alternative 3 are similar to those described above for fry and juvenile rearing WUA, showing little difference in rearing habitat acreages between Alternative 3 and the No Action Alternative in all months (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

Overall, the rearing WUA results indicate that mean fry and juvenile rearing WUA for steelhead is largely similar under Alternative 3 to means under the No Action Alternative.

Rearing Habitat—ASH Analyses

The results of the rearing ASH analysis for fry and juvenile rearing under Alternative 3 show more variation in the means with the water year type than that found in the rearing WUA results described above, with ASH means generally increasing from drier to wetter water year types, except for a minor reduction for juveniles from below normal to above normal water years. This pattern of variation reflects the overall relationship between streamflow and ASH for both life stages determined from modeling and field studies (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in fry and juvenile ASH between Alternative 3 and the No Action Alternative are small, which is consistent with the results of the rearing WUA analyses. For fry rearing, the differences range from 1.7% lower for above normal water years and to 1.3% higher for dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For juvenile rearing, the differences range from 0.8% lower for above normal water years and to 4.2% higher for dry water years. For the individual months of the rearing periods, the median fry rearing ASH is consistently higher under Alternative 3 than under the No Action Alternative, while the median juvenile rearing ASH is lower in December, higher in February and March, and roughly similar in the other months (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that steelhead fry and juvenile rearing ASH is largely similar under Alternative 3 relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimal growth without food limitation year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 38 for Orange Blossom Bridge and Table 40 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 42 for Orange Blossom Bridge and Table 44 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperatures above the 55°F limit of successful smoltification during January through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 48 for Orange Blossom Bridge and Table 50 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-64. Table O-64 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F upper limit of optimal growth without food limitation under Alternative 3, there were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-64). There were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 59.9°F juvenile pathogen virulence threshold, there were one and four month-water year type combinations (1.7% and 6.7%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were three month-water year type combinations (5.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. For the 55°F limit of successful smoltification, there were three month-water year type combinations (12.0% and 20.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River.

These results suggest that Alternative 3 would have positive water temperature-related effects on steelhead juvenile rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

There are expected minor adverse and minor to moderate beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are expected to have a minor increase and/or decrease in fry and juvenile rearing habitat area across all water year types. Water temperatures above the smoltification criteria are expected to have decreases in frequency in the Stanislaus River under Alternative 3.

Adult Upstream Migration and Holding

In the Stanislaus River, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as September and throughout March and can be recovered in the RST in Oakdale from November through April (Hellmair 2022; Eschenroeder et al. 2022).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Average flows in the Stanislaus River below Goodwin Dam are expected to generally decrease September through January and increase February through April during adult migration and holding under Alternative 3 compared to the No Action Alternative (Table O-261 and Table O-262). The largest reduction in flow is a 54% decrease under Alternative 3 in December of a below normal water year type (Table O-261). The largest increase in flow is a 63% increase

under Alternative 3 in March of a below normal water year type. Flows are lowest in September, November, and December of most water year types (except wet water year types) under both the No Action Alternative under Alternative 3. The largest decreases in low flow months under Alternative 3 compared to the No Action Alternative occur in December, with a 26%, 54%, and 27% decrease in above normal, below normal, and dry water year types respectively. Flows below Goodwin Dam are expected to be similar in critically dry water years but are expected to decrease at the Mouth under Alternative 3 compared to the No Action Alternative (Table O-261 and Table O-262).

These results of the CalSim 3 simulated flows suggest that there may be a minor adverse effect of Alternative 3 compared to the No Action Alternative on steelhead adult migration and holding in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range of minimal migration impairment for adult steelhead during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 4 for Orange Blossom Bridge and Table 6 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 8 for Orange Blossom Bridge and Table 10 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult upstream migration and holding pathogen virulence threshold during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 12 for Orange Blossom Bridge and Table 14 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-65. Table O-65 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 41°F to 66.2°F range of minimal migration impairment for adult steelhead under Alternative 3, there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-65). There were zero and one month-water year type combinations (0.0% and 2.2%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence of the San Joaquin River, respectively. For the 69.8°F upper lethal limit to adult migrants there were zero and one month-water year type combination (0.0% and 2.2%, respectively) with favorable results at Orange Blossom Bridge and above the confluence of the San Joaquin River, respectively. There were zero and two month-water year type combinations (0.0% and 4.4%, respectively) with unfavorable results at both Orange Blossom Bridge, and above the confluence of the San Joaquin River, respectively. For the 59.9°F adult upstream migration and holding pathogen virulence threshold there was zero and one month-water year type combination (0.0% and 2.2%, respectively) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were three month-water year type combinations

(6.7%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River.

These results suggest that Alternative 3 would have negligible water temperature-related effects on steelhead adult upstream migration and holding in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

There are expected minor adverse impacts of seasonal operations in the Stanislaus River on adult steelhead based on analyses of simulated flows and water temperature under Alternative 3 compared to the No Action Alternative. Under Alternative 3 compared to the No Action Alternative, there are potential minor adverse impacts of decreased flow in September, November, and December of drier water year types at the mouth of the Stanislaus River for adult migration and holding. Water temperatures outside the range or above the adult migration and holding criteria have negligible decreases in frequency under Alternative 3 compared to the No Action Alternative.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Average flows in the Stanislaus River below Goodwin Dam are expected to be generally increased during kelt emigration under Alternative 3 compared to the No Action Alternative, (Table O-261 and Table O-262). The largest reduction in flow is a 10% decrease under Alternative 3 in March of a critically water year type at the mouth of the Stanislaus River (Table O-262). The largest increase in flow is a 68% increase under Alternative 3 in February of a dry water year type below Goodwin Dam (Table O-261). Flows are expected to be lowest in February and March of drier water year types under the No Action Alternative and Alternative 3. The largest differences in these two months are 61-68% increases in February of dry water year types under Alternative 3. Throughout the full simulation period under Alternative 3 compared to the No Action Alternative, average flows increase throughout the kelt emigration period at both locations (Table O-261 and Table O-262).

These results of the CalSim 3 simulated flows suggest that there are anticipated minor beneficial effects of Alternative 3 compared to the No Action Alternative on steelhead kelt emigration in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F limit of migration impairment for steelhead kelt emigration during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 20 for Orange Blossom Bridge and Table 22 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F lethal limit for steelhead kelt emigration during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 24 for Orange Blossom Bridge and Table 26 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F kelt emigration pathogen virulence threshold during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 28 for Orange Blossom Bridge and Table 30 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-66. Table O-66 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F limit of migration impairment for steelhead kelt emigration under Alternative 3, there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-66). There were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 69.8°F lethal limit for steelhead kelt emigration there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin Rive, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 59.9°F kelt emigration pathogen virulence threshold there were one and four month-water combinations (4.0% and 16.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were zero and one month-water combinations (0.0% and 4.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 3 would have positive water temperature-related effects to steelhead kelt emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

There are expected beneficial impacts of seasonal operations in the Stanislaus River on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 3 compared to the No Action Alternative. Under Alternative 3 compared to the No Action Alternative, there are potential beneficial impacts of flow for kelt emigration. Water temperatures above the lethal limit for kelt emigration and pathogens and disease threshold are expected to decrease in frequency under Alternative 3 compared to the No Action Alternative.

O.6.11 Southern DPS Green Sturgeon

O.6.11.1 Sacramento River

Spawning and Egg Incubation

Southern DPS green sturgeon adults spawn primarily from April through July, although they periodically spawn in late summer and fall (as late as October). Northern DPS green sturgeon eggs hatch about a week after fertilization (at 60ºF), and incubation time of Southern DPS green sturgeon eggs is assumed to be similar (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). Because the incubation time for green sturgeon is so short, the effects analysis period for incubating eggs is considered to be the same as the spawning period, April through July, occasionally extending to October.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

<u>CalSim 3 Flows</u>

During the April through July green sturgeon spawning period, CalSim 3 estimates of mean monthly flows at RBDD under the No Action Alternative and Alternative 3 range from about 4,856 cfs for April of critically dry water years to about 15,277 cfs in April of wet water years (Table O-249). Mean flows during most of this period are moderate (~7,000 cfs to ~12,000 cfs) and likely to be suitable for spawning and egg incubation. Differences in flows at RBDD between Alternative 3 and the No Action Alternative are moderate in most months of the spawning period. Flows are moderately lower for Alternative 3 in April of below normal and dry water years (up to 11%), May of critically dry water years (up to 15%), June of all except dry water years (up to 18%), and July of above normal and below normal water years (up to 15%). Flows substantially increase under Alternative 3 in May of wet and above normal water years (up to 27%) (Table O-249). During the August through October period, when green sturgeon spawning occurs in occasional years, the flows under both alternatives tend to be lower than those in April through July, but the mean flows would be close to or above 5,000 cfs for all water year types in all four months, which is expected to be adequate for green sturgeon spawning and egg incubation. Moderate reductions in mean flows from the No Action Alternative to Alternative 3 are predicted for September of wet and above normal water years (up to 9%). Increased flows are predicted in August of below normal and dry water years (up to 23%) and October of critically dry water years (9%) under Alternative 3 (Table O-249). However, September spawning occurs only sporadically so any effect on the green sturgeon population would be minor (NMFS 2018b). Increases in mean flow from No Action Alternative to Alternative 3 in May, August, or October may or may not be substantial enough to have a positive effect on larval green sturgeon. Flow reductions at RBDD in summer and fall months under Alternative 3 could result in reduced habitat quality in spawning pool and egg incubation habitats, adversely affecting green sturgeon.

CalSim modeling for the Sacramento River at Hamilton City indicates that mean monthly flows during the period of spawning and egg incubation, April through July, are moderately to substantially different between the No Action Alternative and Alternative 3 (Table O-251). Reductions occur in April of below normal and dry water years (up to 9%), May of dry and critically dry years (up to 7%), June of wet, above normal, below normal, and dry water years

(up to 22%), and July of wet, above normal, and below normal water years (up to 19%). Substantial flow increases occur in May of wet and above normal water years (up to 29%) (Table O-251). During the August to October spawning period under Alternative 3, reductions in flows occur in August of wet water years (6%) and September of wet and above normal water years (up to 10%). Moderate to substantial flow increases occur in August of below normal, dry, and critically dry water years (up to 29%) and October of critically dry water years (12%). Moderate increases in mean flow from No Action Alternative to Alternative 3 in May, August, or October may or may not be substantial enough to have a positive effect on larval green sturgeon. Flow reductions at Hamilton City in summer and fall months under Alternative 3 could result in reduced habitat quality in spawning and egg incubation habitats, adversely affecting green sturgeon.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 49.3°F to 63.7°F range for spawning initiation during April through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 208 for Bend Bridge and Table 210 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 52.3°F to 60.8°F range supporting egg incubation during April through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 216 for Bend Bridge and Table 218 for Hamilton City.

Results for the three analyses are summarized in Table O-67. Table O-67, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 49.3°F to 63.7°F spawning initiation range, there were zero and five month-water year type combinations (0% and 25.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-67). There were zero and one combinations (0% and 5.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 52.3°F to 60.8°F range for egg incubation, there were two and one combinations (10.0% and 5.0%, respectively) with favorable results at Bend Bridge and Hamilton City, respectively. There were zero and five combinations (0% and 25.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 3 on green sturgeon spawning and egg incubation.

Summary

Alternative 3 relative to the No Action Alternative is expected to have possible beneficial impacts and adverse impacts on spawning habitats due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have beneficial and adverse impacts on spawning depending on location, month, and water year type due to differences in water temperature.

Larval and Juvenile Rearing and Emigration

The green sturgeon spawning period is from April through July, so the larval period is considered to be April through September. The green sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch. The juveniles rear in the Sacramento River from about May through December. During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). Effects of flow and water temperature on green sturgeon larvae and juveniles may occur from April through December in the Sacramento River when analyzing the two life stages together.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling for the Sacramento River at RBDD indicates that mean monthly flow differences during the April through September period of larval rearing are generally moderate between the No Action Alternative and Alternative 3. Under Alternative 3, reduced flows are predicted for April of below normal and dry water years (up to 11%), May of critically dry water years (15%), June of all except dry water years (up to 18%), July of above normal and below normal water years (up to 15%), and September of wet and above normal water years (up to 9%) (Table O-249). The April, May, June, July, and September reductions in flow from the No Action Alternative to Alternative 3 during various water years would potentially have a minor adverse effect on green sturgeon larvae because, as discussed in Section O.1.3.2.5, *Green Sturgeon, Southern DPS*, there appears to be a positive relationship between annual outflow and abundance of white sturgeon larvae and juveniles, but the applicability of the relationship to green sturgeon is uncertain.

CalSim 3 modeling for the Sacramento River at Hamilton City indicates that mean monthly flow difference during the period of juvenile rearing and emigration, are generally moderate between the No Action Alternative and Alternative 3. Under Alternative 3, reduced flows are predicted for April of below normal and dry water years (up to 9%), May of dry and critically dry water years (up to 7%), June of all except critically dry water years (up to 22%), July of wet, above normal and below normal water years (up to 19%), August of wet water years (6%), and September of wet and above normal water years (up to 10%) (Table O-251). The April, May, June, July, August, and September reductions in flow from the No Action Alternative to Alternative 3 during various water years would potentially have a minor adverse effect on green sturgeon larvae because, as discussed in Section O.1.3.2.5, *Green Sturgeon, Southern DPS*, there appears to be a positive relationship between annual outflow and abundance of white sturgeon larvae and juveniles, but the applicability of the relationship to green sturgeon is uncertain.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 64.4°F upper threshold for larvae from May through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 220 for Bend Bridge and Table 222 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 66.2°F range of optimal juvenile bioenergetic performance

during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 224 for Bend Bridge and Table 226 for Hamilton City.

Results for the three analyses are summarized in Table O-68. Table O-68, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 64.4°F upper water temperature limit for newly hatched larvae, there were one and seven month-water year type combinations (5% and 35.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-68). There were zero and four combinations (0% and 20.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 59°F to 66.2°F range of optimal juvenile bioenergetic performance, there was one combination (6.7%) with favorable results at both locations. There were six and two combinations (40.0% and 13.3%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 3 on green sturgeon larval and juvenile rearing and emigration.

Summary

Alternative 3 relative to the No Action Alternative is expected to have possible adverse impacts on rearing and emigration due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have beneficial and adverse impacts on rearing and emigration depending on location, month, and water year type due to differences in water temperature.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Sacramento River from the Delta as early as February to make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence. After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). With the extended adult holding period, effects of flow and water temperature on adult upstream migration and holding may occur from February through December.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

Flow differences during the February through December period of green sturgeon upstream migration and holding would generally be moderate between Alternative 3 and the No Action Alternative at RBDD, Hamilton City, and Wilkins Slough (Table O-249 through Table O-251). CalSim 3 model results predict substantially higher mean monthly flows under Alternative 3 at all locations during May of wetter years (up to 37%) and August (up to 43%) of drier years. Substantially lower flows under Alternative 3 occur during June and July of wetter water years (up to 28% and 26%, respectively) at Hamilton City and Wilkins Slough. September and November are predicted to have moderately reduced flows at all locations during wet and above normal water years. Substantial increases in mean flow from No Action Alternative to Alternative 3 in May and August may be enough to have a beneficial effect on migrating and

holding adult green sturgeon. All of the more notable flow differences occur within a range of river flows (~3,500 cfs to 12,000 cfs) that are not expected to substantially affect upstream passage of migrating green sturgeon, but the June and July flow reductions under Alternative 3 at all locations could result in reduced habitat quality in holding pool habitats, adversely affecting holding adults.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52°F to 69.4°F range for adult migration during April through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 204 for Bend Bridge and Table 206 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 52°F to 73.4°F range for adult holding year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 212 for Bend Bridge and Table 214 for Hamilton City.

Results for the two analyses are summarized in Table O-69. Table O-69 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%. If the exceedance or occurrence value was >10% lower under the alternative relative to the No Action Alternative, the result is termed "Favorable". If the exceedance or occurrence value was >10% higher under the alternative relative to the No Action Alternative, the result is termed "Unfavorable". The 10% value was chosen to represent a level of difference between the alternative and the No Action Alternative that could have a biologically meaningful effect on the species but considers the coarse definition in the data (e.g., a difference in just one of the 14 above normal water years represents a 7% difference). This value should not be interpreted as a significance threshold.

Under Alternative 3 for the 52°F to 69.4°F range for adult migration, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable or unfavorable results at both Bend Bridge and Hamilton City, respectively (Table O-69). For the 59°F to 73.4°F range for adult holding, there was one combination (1.7%) with favorable results at both Bend Bridge and Hamilton City. There were 15 and one combinations (25.0% and 1.7%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be negative effects and negligible positive water temperature-related effects of Alternative 3 on green sturgeon adult upstream migration and holding.

Summary

Alternative 3 relative to the No Action Alternative is expected to have potential beneficial impacts and adverse impacts on migration and holding habitat due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have adverse impacts and negligible beneficial impacts on migration and holding depending on location, month, and water year type due to differences in water temperature.

O.6.11.2 San Joaquin River

Green sturgeon are also present in the San Joaquin River, but at considerably lower numbers than white sturgeon. Anglers have reported catching green sturgeon in the San Joaquin River and one adult green sturgeon was captured by Reclamation in April of 2020 (Root et al., 2020 [research note]). Although the reported presence of green sturgeon in the San Joaquin River coincides with the spawning migration period of green sturgeon within the Sacramento River, no evidence of spawning has been detected (Section O.1.8.2.3, *Green Sturgeon, Southern DPS*).

Potential Changes to Green Sturgeon from Seasonal Operations

CalSim 3 Flows

Since green sturgeon spawning has not been confirmed in the San Joaquin River, life stage analyses were not performed. It is assumed that adult green sturgeon could be in the San Joaquin River during all months of the year.

During the evaluated months, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 3 range from about 466 cfs for July of critically dry water years to about 13,336 cfs for February of wet water years (Table O-263). CalSim 3 results predict moderately to substantially decreased flows under Alternative 3 compared to the No Action Alternative during all months except February and May of various water year types. Substantially decreased flows are predicted for April and July through September of all water years (up to 22% in July of wetter water years). Moderate decreases in flows are predicted for January of above normal water years (7%), March of critically dry water years (10%), June of above normal, below normal, and critically dry water years (up to 6%), October of all water years (up to 7%), and November and December of above normal, below normal, and dry water years (up to 10%) (Table O-263). Because green sturgeon are uncommon in the San Joaquin River and can easily relocate to other parts of the Bay Delta system that have adequate flow, it is not anticipated that flow reductions under Alternative 3 would have an effect on green sturgeon compared to the No Action Alternative.

Summary

Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on adult green sturgeon due to differences in flow. Due to the lack of information about green sturgeon life stages in the San Joaquin River, a temperature analysis was not done for this species in this geography.

O.6.11.3 Bay-Delta

Larval and Juvenile Rearing and Emigration

After hatching, larvae and juveniles migrate downstream toward the Delta. Juveniles are believed to use the Delta for rearing for the first one to three years of their lives before moving out to the ocean and are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, especially within the central Delta and Suisun Bay/Marsh (Section O.1.9.1.5, *Green Sturgeon, Southern DPS*).

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

Zone of Influence

Differences in hydrology under Alternative 3 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. With incremental decreases in OMR under Alternative 3 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under Alternative 3 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 3, Sacramento River Winter-run Chinook Salmon ESU (Section O.6.8.2, *Zone of Influence*).

Flow into Junctions

For a full description of Flow into Junctions model background, see Section O.4.8.2, *Sacramento River Winter-run Chinook Salmon ESU, Juvenile Rearing and Emigration in the Bay-Delta*. The following section covers discussion of the Central Valley Project and Head of Old River junctions. An expanded set of junction analysis results can be found in Attachment I.10, *Flow into Junctions*.

Under Alternative 3 in the -2,000 and -3,500 OMR bins, predicted proportion of flow entering the Central Valley Project (CVP) is greater than the No Action Alternative, and less than the No Action Alternative in the -5,000 and <-5,500 OMR bins. Changes in predicted proportion of flow entering the CVP when OMR was -2,000, -3,500, and -5,000 were less than ± 0.0406, indicating a negligible difference from the No Action Alternative. However, when OMR was <-5,500 the change in flow into CVP was -0.0933, indicating that slightly less flow will be routed into CVP under Alternative 3 than when compared to the No Action Alternative.

Under Alternative 3 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the Head of Old River (HOR) is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.0404, indicating a negligible difference between Alternative 3 and the No Action Alternative.

Delta Outflow vs. Sturgeon YCI

There are currently no tools available to directly evaluate the effect of spring outflow on green sturgeon thus white sturgeon are used as a proxy species for green sturgeon. To evaluate the effect of spring outflow on green sturgeon a Delta Outflow vs Year-Class Strength[1] regression analysis was done. This analysis is a response to the NMFS Green Sturgeon Recovery Plan that suggested larval abundance and distribution may be influenced by spring and summer outflow. The recovery plan also suggested that recruitment may be highest in wet years, making water flow an influential habitat parameter (National Marine Fisheries Service 2018a:12). As noted by

[1] Year-class strength in this case is an index of year-class abundance based on age-0 and age-1 white sturgeon abundance indices from otter trawling by the San Francisco Bay Study (Fish 2010).

NMFS (2018b:12), there are correlations between white sturgeon and Delta outflow, which have previously been used to infer potential effects on green sturgeon (ICF International 2016).

In contrast to white sturgeon, there are currently no quantitative relationships established between green sturgeon and Delta flows. There appears to be a positive relationship between annual outflow and abundance in rotary screw traps at Red Bluff Diversion Dam of green sturgeon larvae and juveniles (Heublein et al. 2017a). More recently, CDFW found that catch per unit effort of yearling juvenile green sturgeon sampled in the Delta was about 10 times as high in years following wet water years as in years following dry and critically dry water years (Beccio 2021). These factors are generally suggestive of a positive relationship with flow, but it is uncertain the extent to which such effects may reflect water operations.

The Delta Outflow Year-Class Strength regression analysis found statistically significant positive correlations between white sturgeon year-class strength and Delta outflow for April-May and March-July. The analysis is used as a surrogate for green sturgeon. For the April-May Delta outflow, the average overall YCI values would be substantially increased under Alternative 3 (18) relative to the No Action Alternative (11.2), a 59.9% relative increase (Table O-70). The same is true for the March-July Delta outflow, with the average overall YCI value for Alternative 3 being 22.4 compared to 16.7 for the No Action Alternative, a 34.2% relative increase (Table O-71). Effects of Alternative 3 on green sturgeon relative to the No Action Alternative are expected to be positive given the substantial increases in average Delta flow conditions between the two alternatives over all water year types during the specified months. For more detailed information see summaries presented in Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*.

<u>Summary</u>

Alternative 3 relative to the No Action is expected to influence flow into the Head of Old River and CVP junctions. Under Alternative 3, no change to possibly less flow into CVP under OMR -3,500; no change in flow into HOR under OMR groupings. Impacts of pumping under both Alternative 3 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI). Alternative 3 relative to the No Action Alternative is expected to have minor beneficial impacts on green sturgeon year class strength using white sturgeon as a proxy for green sturgeon due to differences in flow.

Potential Changes to Entrainment of Southern DPS Green Sturgeon

<u>Salvage Density</u>

Predictions from the salvage density model for green sturgeon include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of green sturgeon at SWP Banks Pumping Plant for the months January, and March of all water year types Alternative 3 was less than or equal to predicted average monthly loss under the No Action Alternative for all water year types except for the below normal year type that had an increase of 1%. For all other water year types Alternative 3 had a lower or equal predicted loss of green sturgeon at Banks compared to the No Action Alternative with up to a 58% reduction in loss for wet water year types (Table O-72). Predicted average monthly loss of green sturgeon at CVP Jones Pumping Plant for all the months June through July Alternative 3 had equal or lower predicted average monthly loss compared to the No Action Alternative for all water year types, with up to a 89% reduction in predicted loss for dry water year types (Table O-73). It should be noted that loss of green sturgeon at both facilities is rare and infrequent, with such low values of predicted loss the percent differences may not be representative. For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Summary

Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on the entrainment of juvenile green sturgeon at both facilities due to differences in flow. Modeled results from the quantitative model shows possible beneficial impacts, but since green sturgeon are salvaged so rarely, the numbers may not be representative.

Adult Upstream Migration and Holding

Adult green sturgeon move through the Delta from February through April to get to spawning locations in the upper Sacramento River. Following their initial spawning run upriver, adults split into two out migration groups, the "early" out migration group may migrate immediately back downstream through the Delta during May and June, or the "late" out migration group may hold for a few weeks to months in the upper river before moving back downstream during November through January (Section O.1.9.1.5, *Green Sturgeon, Southern DPS*).

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

Delta Outflow vs. Sturgeon YCI

The Delta outflow vs Sturgeon YCI regression analysis results apply to all life stages of green sturgeon found in the Bay Delta. The regression analysis, used as a surrogate for green sturgeon, found statistically significant positive correlations between white sturgeon year-class strength and Delta outflow for April-May and March-July. Under Alternative 3, April-May Delta outflow average overall YCI values would be 59.9% higher (Table O-70) and the March-July Delta outflow values would be 34.2% higher (Table O-71) compared to the No Action Alternative. Refer to the analysis in Section O.6.11.3.1, *Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 3 relative to the No Action Alternative is expected to have beneficial impacts on green sturgeon year class strength due to differences in flow.

O.6.12 Delta Smelt

O.6.12.1 Bay-Delta

Adult Migration and Spawning

During winter, adult Delta smelt initiate upstream spawning migration in association with "first flush" flow events (Sommer et al. 2011). Others report this seasonal change as a multi-directional and more circumscribed dispersal movement to freshwater areas throughout the Delta region (Murphy and Hamilton 2013). By late winter-spring, after arriving in freshwater staging habitats, adult Delta smelt hold until spawning commences during favorable water temperatures (Bennett 2005; Grimaldo et al. 2009; Sommer et al. 2011; Damon et al. 2016). Delta smelt spawn over a wide area throughout much of the Delta, including the Sacramento River and San Joaquin River confluence, the upper Sacramento River, and Cache Slough as well as into Suisun Marsh and the Napa River as conditions allow (Brown et al. 2014; Murphy and Hamilton 2013). Spawning of Delta smelt has not been observed in the wild (Moyle et al. 2016).

Potential Changes to Delta Smelt from Seasonal Operations

<u>CalSim 3 X2 Modeled X2 Position</u>

The position of X2 under Alternative 3 ranged from similar to further seaward when compared to the No Action Alternative (Table O-252) during the adult Delta smelt migration and spawning period, varying 0-7 km from the No Action Alternative, likely having beneficial effects on adult Delta smelt in the winter and spring.

<u>USFWS Delta Smelt Life Cycle Model</u>

The geometric mean of the expected rate of change in abundance across years (1995-2015), λ, for Alternative 3 was 1.16 (Attachment F.4., *Delta Smelt Life Cycle Model with Entrainment*). This is substantially higher than the λ values for all other Alternatives. Like other Alternatives, the geometric means of the expected population growth rate under Alternative 3 varied between water year types, from λ equal to 0.90 (-10% decline on average) for below normal, dry and critically dry water years, to λ equal to 1.53 (53% increase in abundance on average) for wet and above normal years. Compared to the No Action Alternative, the results under Alternative 3 were more positive and ranged from 20% to 29% higher than the No Action Alternative in terms of population growth rates, depending on the water year type (Attachment F.4., *Delta Smelt Life Cycle Model with Entrainment*).

<u>Revised Maunder and Deriso Life Cycle Model</u>

Based on life cycle analysis with the revised Maunder and Deriso in R (MDR) model, relative to the No Action Model, model projections under Alternative 3 indicate a substantial beneficial impact, with Delta smelt population growth rate larger than for the No Action Alternative in all modeled years (1995-2015; Attachment F.1, *Maunder and Deriso in R Model*). The geometric mean of λ was 0.97 under Alternative 3 across all water year types, 28% higher than for the No Action Alternative (λ = 0.75), and the magnitude of this difference remained similar for both drier and wetter water years.

Because the MDR is an integrated life cycle model, the effects of each Alternative were evaluated quantitatively primarily based on year-to-year changes in the population growth rate metric. However, as a statistical model fitted to abundance data for multiple life-stages, it is possible to gain a qualitative understanding of the season-specific covariates with a statistically significant influence on each life-stage. Also, because the covariates are standardized prior to model fitting, their coefficients can be directly compared.

In the MDR model, survival from the sub-adult to adult stage can be influenced by winter covariates which are averaged across the December to February period. Model selection retained combined Old and Middle River flow (OMR) and mean Secchi depth at South Delta monitoring stations as significant covariates of sub-adult survival, with coefficients of 0.477 and 0.542, respectively. Although differences in hydrology between the Alternatives would be expected to influence turbidity, the relationship is complex and was not able to be addressed for this analysis. Within the MDR, impacts on sub-adult survival are therefore related only to differences in OMR between the Alternatives. Winter OMR was 65% higher (i.e. less negative), on average, for Alternative 3 than under the No Action Alternative, a difference which likely accounts for the majority of the beneficial impact on population growth relative to the No Action Alternative.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the winter in the low salinity zone showed significant relationships for five zooplankton taxa; *Daphnia* adults, decapod larvae, *Eurytemora affinis* adults, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 3, when compared to the No Action Alternative, *Daphnia* adults had the largest expected CPUE increase of 22% during the below normal water year and the smallest expected CPUE increase of 4% during the wet water year type. Results for decapod larvae were negligible when rounded to the nearest whole integer (values were 0) across all WYT and scenarios. *E. affinis* adults had the largest expected CPUE increase of 13% during the dry water year type and the smallest expected CPUE increase of 5% during the wet water year type. Other calanoid copepod adults had the largest expected CPUE increase of 33% during the below normal and dry water year type and the smallest expected CPUE increase of 12% during the wet water year type. Other calanoid copepodites had the largest expected CPUE increase of 21% during dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 3 are generally higher than the No Action Alternative for winter months and water year types (Table O-254) resulting in higher zooplankton CPUE.

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 3, when compared to the No Action Alternative, cladocearns (except *Daphnia*) had the largest expected CPUE increase of 20% during the critically dry water year type and the smallest expected CPUE increase of 10% during the wet water year type. *E. affinis* adults had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Harpacticoids had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE

increase of 7% during the wet water year type. Other calanoid copepod adults had the largest expected CPUE increase of 15% during the critically dry water year type and the smallest expected CPUE increase of 9% during the wet water year type. Other calanoid copepod copepodites had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 6% during the wet water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 3 are generally higher than the No Action Alternative for spring months and water year types (Table O-254) resulting in higher zooplankton CPUE.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a beneficial impact on adult Delta smelt migration and spawning due to differences in flow. Compared to the No Action Alternative, CPUE of Delta Smelt prey species is expected to be higher under Alternative 3. Results from the revised and Deriso life cycle model indicate that under Alternative 3 there would be a substantially higher population growth rate. These results generally agreed with the results from the USFWS life cycle models which found population increases under Alternative 3 ranging from 21 -23% higher when compared to the No Action Alternative depending on the water year type. CalSim 3 results indicate that the position of X2 ranged from no different to further seaward when compared to the No Action Alternative during the winter and spring depending on the water year type, which is expected to have no impact to beneficial impacts on adult Delta smelt migration and spawning.

Potential Changes to Entrainment of Delta Smelt

Alternative 3 relative to the No Action Alternative may affect the entrainment of adult Delta smelt. Entrainment varies annually and depends on a combination of hydrology, turbidity, and export rates (see Smith et al. 2021). Historic salvage shows adult Delta smelt are entrained in the Delta Fish Collection Facilities, however in more recent years fewer fish have been entrained likely due to a combination of changes to operations and the continued decline of the Delta smelt population. While the USFWS life cycle model does incorporate entrainment, it was not used to evaluate entrainment of adult Delta smelt. Instead, OMR flows were used to evaluate changes between Alternative 3 and the No Action Alternative.

CalSim 3 OMR Values

OMR combined flows was less negative under Alternative 3 when compared to the No Action Alternative from January to June which would have substantial positive effects on entrainment of adult Delta smelt (Table O-255). The largest difference in OMR flows were in April during the wet water year type (375% less negative), while the smallest difference was June during the critically dry water year type (28% less negative). In general, during the January to June period, OMR was less negative under Alternative 3 compared to No Action Alternative which would be beneficial for adult Delta smelt entrainment.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a beneficial impact on the entrainment of adult Delta smelt due to differences in flow. Differences in OMR flow between Alternative 3 and the No Action Alternative are in general less negative from January to June, which can lead to decreased entrainment of adult Delta smelt.

Eggs and Larvae

Eggs hatch after an average of 10 days in the spring and planktonic larvae are transported (advected) from freshwater regions by the Sacramento River and tidal flows from March through May. The larval stage lasts for an average of 30 days. The nonpelagic habitats used by larval Delta smelt before they move into the pelagic areas are not known (Swanson et al. 1998; Sommer et al. 2011).

Potential Changes to Delta Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

While Delta smelt can occupy a wide range of habitats and salinities, historically a majority of Delta smelt reside in or near the LSZ (Merz et al. 2011, Moyle et al. 1992). X2 has been used as a proxy for the LSZ (MacWilliams et al. 2015, Kimmerer et al. 2013, Jassby et al. 1995). The position of X2 responds to CVP and SWP operations, the more freshwater outflow into the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and at the confluence of the Sacramento and San Joaquin Rivers (X2 ~ 80-85 km).

The position of X2 under Alternative 3 was further seaward compared to the No Action Alternative (Table O-252) during the larval Delta smelt period, varying 1-5 km from the No Action Alternative depending on water year type, likely having no to beneficial effects on larval Delta smelt in the spring.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for 5 zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 3, when compared to the No Action Alternative, cladocearns (except *Daphnia*) had the largest expected CPUE increase of 20% during the critically dry water year type and the smallest expected CPUE increase of 10% during the wet water year type. *E. affinis* adults had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Harpacticoids had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Other calanoid copepod adults had the largest expected CPUE increase of 15% during the critically dry water year type and the smallest expected CPUE increase of 9% during the wet water year type. Other calanoid copepod copepodites had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 6% during the wet water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 3 are generally higher than the No Action Alternative for spring months and water year types (Table O-254) resulting in higher zooplankton CPUE.

Revised Maunder and Deriso Life Cycle Model

Life cycle analysis with the revised Maunder and Deriso Model in R (MDR) did not identify any significant covariates of recruitment, and so did not evaluate effects on eggs or early larval stages.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a beneficial impact on Delta smelt larvae due to differences in flow. Compared to the No Action Alternative, CPUE of Delta Smelt prey species is expected to be higher under Alternative 3. Results from the Maunder and Deriso life cycle model indicate that under Alternative 3 there would be a slight beneficial impact on the survival of post-larval Delta smelt under Alternative 3. CalSim 3 results indicate that the position of X2 was further seaward (1–5 km) from the No Action Alternative during the spring which are expected to have no to beneficial impacts on larval Delta smelt.

Potential Changes to Entrainment of Delta Smelt

Alternative 3 relative to the No Action Alternative may affect the entrainment of Delta Smelt larvae due to differences in flow. This possible difference was evaluated using a quantitative model.

Particle Tracking Model (PTM)

The CalSim 3 model simulated operational conditions under a range of OMR and inflow conditions from the Sacramento and San Joaquin rivers, with the DSM2 PTM module allowing for an assessment of entrainment of neutrally buoyant passive particles (a proxy for larval Delta smelt, generally distributed throughout the water column) at export facilities (Attachment I.8, *Particle Tracking Fate Modeling of Larval Smelt Entrainment*). PTM analysis was only considered for the larval Delta smelt life stage since modeling suggests later Delta smelt life stages are likely not neutrally buoyant and have a behavioral response to maintain horizontal position in the estuary (Gross et al. 2021, Kimmerer and Nobriga 2008). Results discussed here are expressed as percent of particles with a fate of *Entrained at Exports*. Please refer to Attachment I.3, *Delta Export Zone of Influence Analysis*, for keys to inflow and OMR bins codes, including corresponding Sacramento and San Joaquin rivers flow ranges and mean OMR and Exports flow ranges. While a complete set of detailed results is presented in Attachment I.8, *Particle Tracking Fate Modeling of Larval Smelt Entrainment*, the following narrative focuses on three injection regions when assessing potential entrainment effects from the perspective of varying inflows (Inflow bins: *Sacramento River, San Joaquin River,* and *Yolo Bypass Region*) and one injection region when assessing potential effects from the perspective of OMR net flows (OMR bins: *San Joaquin River Region*).

Inflow Bins.

Depending on inflow conditions, an average of 0 to 3% of particles injected within the Sacramento River region ended up entrained at export facilities under Alternative 3, compared to 0 to 14% under the No Action Alternative. Regardless of inflow conditions, Alternative 3 would always lead to reductions in the average percentage of particles entrained at export facilities, ranging from -87% under “medmed” inflow conditions to 0% under “hilo” inflow conditions.

Depending on inflow conditions, an average of 21 to 82% of particles injected within the San Joaquin River region ended up entrained at export facilities under Alternative 3, compared to 45 to 87% under the No Action Alternative. Regardless of inflow conditions, Alternative 3 would always lead to reductions in the average percentage of particles entrained at export facilities, ranging from -6% under "hilo" inflow conditions to -59% under "medhi" inflow conditions. Although not discussed here in detail, a similar pattern was observed for other injection regions with moderate potential for particles entrainment. Alternative 3 would generally lead to reductions in the average percentage of particles entrained compared to the No Action Alternative under all inflow conditions excluding "hilo" inflow conditions which ranged from 5% increase for the Mokelumne River injection region to 6% increase for the Central Delta injection region.

Depending on inflow conditions, an average of 0 to 1% of particles injected within the Yolo Bypass region would end up entrained at export facilities under Alternative 3, compared to 0 to 5% under the No Action Alternative. Based on inflow conditions, Alternative 3 would almost always lead to reductions in the average percentage of particles entrained at export facilities, ranging from -30% under "himed" inflow conditions to -94% under "medhi" inflow conditions. The 23% increase in particles related to "hilo" inflow conditions is associated with the percent difference calculation, however there was a negligible difference in entrained particles between the NAA and Alternative 3 under these conditions.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), there was a difference between the average percentage of particles entrained under Alternative 1 and under the No Action Alternative (-1 to -69%).

OMR Bins.

Depending on OMR flow conditions, an average of 51 to 80% of particles injected within the San Joaquin River region would be entrained at export facilities under Alternative 3, compared to 57 to 87% under the No Action Alternative. Potential entrainment ranged from 11% lower under Alternative 3 than under the No Action Alternative for the -2000 OMR bin (51% *vs* 57%) to little or no difference for the -3500 bin between the No Action Alternative and Alternative 3 (68% vs 59%, respectively). Although not discussed here in detail, a similar pattern of slight reductions or similar entrainment rates under -2000 and -5000 OMR Bins, and a slight increase in entrained particles under -3500 OMR Bin was observed for Mokelumne River, Sacramento River, Central Delta export facilities. Alternative 3 would generally lead to substantial reductions in the average percentage of particles entrained compared to the No Action Alternative for the most negative OMR index (-5000: -37 to -75%), negligible reductions under the less negative OMR index (-2000: -5% to 11%) and increases under intermediate OMR index (-3500: +20 to +97%).

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of OMR flow conditions, there was generally little difference between the average percentage of particles entrained under Alternative 3 and under the No Action Alternative (-3 to +1%).

Summary

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), Alternative 3 relative to the No Action Alternative, is expected to have a negligible to beneficial impact on the entrainment of Delta smelt for all inflow groupings. For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta) Alternative 3 relative to the No Action Alternative is expected to have a negligible impact on the entrainment of Delta smelt, depending on OMR grouping.

Juveniles

During and after larval rearing in freshwater, many young Delta smelt move with river and tidal currents during the early summer to remain in favorable rearing habitats, often moving into low salinity (≤ 6 psu) areas to avoid seasonally warm and highly transparent waters that typify many areas in the central Delta (Nobriga et al. 2008). Juvenile Delta smelt rearing habitat is correlated with salinity, particularly the position of the LSZ, and other habitat attributes such as turbidity and temperature. Delta smelt also rear in upstream areas such as the Cache Slough complex and Sacramento Deep Water Ship Channel, depending on habitat conditions (Sommer and Mejia 2013). Studies indicate that in fall, prior to spawning, juvenile and sub-adult Delta smelt tend to remain in the LSZ (Sommer et al. 2011), though they can be found in the lower San Joaquin River, Suisun and San Pablo bays, the Sacramento River and San Joaquin River confluence, Cache Slough, and the lower Sacramento River (Murphy and Hamilton 2013).

Potential Changes to Delta Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 3 ranged from similar to the No Action Alternative to further seaward (Table O-252) during the juvenile Delta smelt period, varying 0–5 km from the No Action Alternative, likely having no to beneficial effects on juvenile Delta smelt in the summer depending on water year type. During the fall period, CalSim 3 modeling indicates that the estimated X2 position under Alternative 3 when compared to the No Action Alternative ranged from no different to further seaward (0–5 km), which would have no to beneficial effects for juvenile Delta smelt.

Habitat Suitability Index

Juvenile Delta smelt summer and fall habitat was estimated for different water year types (wet, above normal, below normal, dry, and critical) using the Bever et al. (2016) habitat suitability index (Bever HSI) and the Bever HSI with a water temperature threshold of 22° Celsius (22C HSI), where the Bever HSI value is multiplied by 0 when water temperature is greater than 22° C and by 1 when water temperature is less than or equal to 22° C. The temperature threshold of 22ºC was used based on sub-lethal physiological and behavioral effects observed in multiple studies (Davis et al. 2022, Hammock et al. 2022; Komoroske et al. 2021; Lewis et al. 2021; Davis et al. 2019; Komoroske et al. 2015). Under Alternative 3, mean Bever HSI for subregions targeted by the summer fall habitat action (Yolo Bypass, which includes Cache Slough and Sacramento Deepwater Shipping Channel; Lower Sacramento River; Confluence; Suisun Marsh; northwest Suisun Bay) was 5% lower to almost 6% higher than under the No Action Alternative, depending on water year type. Under Alternative 3, the mean 22C HSI for the summer fall habitat action subregions was 10% lower to almost 6% higher than under the No Action

Alternative, depending on water year type. The largest differences under Alternative 3 are predicted during the dry water year for mean Bever HSI (6% higher) and during the above normal water year for mean 22C HSI (10% lower). The smallest differences are predicted during the below normal water year for mean Bever HSI (< 1% higher) and for mean 22C HSI (2% lower).

The results of the HSI analyses suggest that Alternative 3 may result in minor increases (1%–6%) and minor decreases (2%–10%) in suitable habitat depending on water year type and the application of a temperature threshold in comparison to the No Action Alternative and would likely have minor beneficial to minor adverse impacts on juvenile Delta smelt summer and fall habitat.

Revised Maunder and Deriso Life Cycle Model

Summer outflow, the only variable within the revised Maunder and Deriso Model in R (MDR) with influence on the larval life-stage, varied little between alternatives (Attachment F.1, *Maunder and Deriso in R Model*). However, Alternative 3 was the only alternative under which outflow increased relative to the No Action Alternative (approximately 6% higher outflow than No Action Alternative), indicating that, on average, a slight, beneficial impact on the survival of post-larval Delta smelt would result under Alternative 3.

The preferred set of covariates identified through extensive model selection did not include parameters that differed between alternatives (Attachment F.1, *Maunder and Deriso in R Model*). Mean Delta water temperature and Secchi depth were the selected parameters for the fall period, which correspond to juvenile survival in the MDR model. Although hydrological differences between the alternatives would potentially impact these variables, the relationships between flow, temperature and turbidity are complex, and were not able to be modeled for this exercise. As such, juvenile Delta smelt survival under Alternative 3 was the same as under the No Action Alternative.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the fall showed significant relationships for two taxa; *E. affinis* adults and mysids. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 3, when compared to the No Action Alternative, *E. affinis* had the largest expected CPUE increase of 33% for the wet water year type and no expected change in CPUE for the above normal, below normal, dry, and critically dry water year type. However, the expected CPUE for *E. affinis* during the fall was very low (1–3 individuals per cubic meter) and unlikely to impact Delta smelt juveniles. Mysids had the largest expected CPUE increase of 25% during the above normal water year type and no expected change in CPUE for the critically dry water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 3 are generally higher than the No Action Alternative for November for most water year types (Table O-254) resulting in higher zooplankton CPUE.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a beneficial impacts and adverse impacts on juvenile Delta smelt due to differences in flow. CalSim 3 results indicate that the position of X2 ranged from no different to further seaward, depending on water year type, compared to No Action Alternative during the summer and fall which are expected to have beneficial impacts on juvenile Delta smelt. The results of the HSI analyses suggest that Alternative 3, depending on water year type and the application of a temperature threshold, in comparison to the No Action Alternative would likely have minor beneficial to adverse impacts on juvenile Delta smelt summer and fall habitat. Results from the revised Maunder and Deriso life cycle model did not include parameters that differed between alternatives therefore juvenile survival under Alternative 3 was the same as under the No Action Alternative. Compared to the No Action Alternative, CPUE of Delta smelt prey species was not related to outflow in the summer and is expected to be higher than the No Action Alternative during the fall.

Potential Changes to Entrainment of Delta Smelt

Alternative 3 relative to the No Action Alternative may affect the entrainment of juvenile Delta smelt due to differences in flow. Entrainment varies annually and depends on a combination of hydrology, turbidity, and export rates (see Smith et al. 2021). Historic salvage shows juvenile Delta smelt are entrained in the Delta Fish Collection Facilities, however in more recent years fewer fish have been entrained likely due to a combination of changes to operations and the continued decline of the Delta smelt population. While the USFWS life cycle model does incorporate entrainment, it was not used to evaluate entrainment of adult Delta Smelt. Instead, OMR flows were used to evaluate changes between Alternative 3 and the No Action Alternative.

CalSim 3 OMR Values

OMR combined flows generally was less negative under Alternative 3 when compared to the No Action Alternative from June to November, which would have positive effects on entrainment of juvenile Delta smelt (Table O-255). The largest difference in OMR flows under Alternative 3 compared with the No Action Alternative was in August during the wet water year type (65% less negative), while OMR flows were more negative in October during the dry year type (13% more negative) compared to the No Action Alternative. In general, during the June to November period, OMR was less negative under Alternative 3 compared to No Action Alternative, which would have beneficial effects on juvenile Delta smelt entrainment.

O.6.13 Longfin Smelt

O.6.13.1 Bay Delta

Adult Migration and Spawning

Longfin smelt are anadromous and spawn in fresh or low-salinity water in the Bay-Delta (Grimaldo et al. 2017), generally at two years of age (Moyle 2002). A portion of the population migrate from the ocean into the San Francisco Estuary and move upstream to spawn during late fall through winter, with most spawning occurring from November through April (California Department of Fish and Wildlife 2009a). Spawning locations have been estimated using field observations of gravid females and yolk-sac larvae (Grimaldo et al. 2017, Lewis et al. 2019) and through particle-tracking modeling (Gross et al. 2022) to suggest spawning extends farther

seaward than previously thought (Moyle 2002). Based on these studies, longfin smelt appear to spawn in the low-salinity zone where brackish and freshwaters meet (Grimaldo et al. 2017), and in tidal wetlands of south San Francisco Bay and San Pablo Bay when hydrological conditions favor spawning in more seaward regions (Lewis et al. 2020, Grimaldo et al. 2020). These regions include marshes of the Petaluma watershed, Napa-Sonoma watershed, Sacramento-San Joaquin watershed, and Coyote Creek watershed (Lewis et al. 2020, Hobbs et al. 2015).

Potential Changes to Longfin Smelt from Seasonal Operations

CalSim 3 Modeled X2 Position

The position of X2 under Alternative 3 ranged from similar to further seaward compared to the No Action Alternative (Table O-252) during the adult longfin smelt migration and spawning period, varying 0-7 km from the No Action Alternative, likely having negligible to beneficial impacts on adult longfin smelt in the fall, winter and spring.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the winter in the low salinity zone showed significant relationships for 5 zooplankton taxa; *Daphnia* adults, decapod larvae, *Eurytemora affinis* adults, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 3, when compared to the No Action Alternative, *Daphnia* adults had the largest expected CPUE increase of 22% during the below normal water year and the smallest expected CPUE increase of 4% during the wet water year type. Results for decapod larvae were negligible when rounded to the nearest whole integer (values were 0) across all WYT and scenarios. *E. affinis* adults had the largest expected CPUE increase of 13% during the dry water year type and the smallest expected CPUE increase of 5% during the wet water year type. Other calanoid copepod adults had the largest expected CPUE increase of 33% during the below normal and dry water year type and the smallest expected CPUE increase of 12% during the wet water year type. Other calanoid copepodites had the largest expected CPUE increase of 21% during dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 3 are generally higher than the No Action Alternative for winter months and water year types (Table O-254) resulting in higher zooplankton CPUE.

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for 5 zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 3, when compared to the No Action Alternative, cladocearns (except *Daphnia*) had the largest expected CPUE increase of 20% during the critically dry water year type and the smallest expected CPUE increase of 10% during the wet water year type. *E. affinis* adults had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Harpacticoids had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Other calanoid copepod adults had the largest expected CPUE increase of 15% during the critically dry water year type and the smallest expected CPUE increase of 9% during the wet water year type. Other calanoid copepod

copepodites had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 6% during the wet water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflow under Alternative 3 are generally higher than the No Action Alternative for spring months and water year types (Table O-254) resulting in higher zooplankton CPUE.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a beneficial impact on adult longfin smelt migration and spawning due to differences in flow. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to increase under Alternative 3 during the fall, winter and spring. The position of X2 under Alternative 3 ranged from similar to further seaward when compared to the No Action Alternative likely resulting in negligible to beneficial impacts on adult longfin smelt migration and spawning.

Potential Changes to Entrainment of Longfin Smelt

Alternative 3 relative to the No Action Alternative may affect the entrainment of adult longfin smelt due to differences in flow. Entrainment varies annually and depends on a combination of hydrology and export rates.

CalSim 3 Modeled X2 Position

The position of X2 under Alternative 3 was further seaward (lower) compared to the No Action Alternative (Table O-252) during the adult longfin smelt migration and spawning period, varying 0 to -7 km (further seaward) from the No Action Alternative depending on the month and water year type.

CalSim 3 Total Exports and OMR Values

Total exports during the adult longfin smelt migration and spawning period under Alternative 3 decreased when compared to the No Action Alternative across the entire longfin smelt migration and spawning period. OMR flow values were less negative compared to the No Action Alternative across the entire longfin smelt migration and spawning period (Table O-255). Compared to the No Action Alternative, under Alternative 3, there is likely a beneficial effect on adult longfin smelt during the spawning and migration period when compared to the No Action Alternative since total exports were lower and OMR values were less negative and under the -5000 cfs threshold.

Summary

Alternative 3 relative to the No Action Alternative may have negligible to beneficial impacts on entrainment of adult longfin smelt during migration and spawning, due to differences in flow. Compared to the No Action Alternative, the position of X2 varied 0-7 km further seaward under Alternative 3, likely having a beneficial impact on entrainment of adult longfin smelt. Exports were lower and OMR values were less negative under Alternative 3 when compared to the No Action Alternative likely having a beneficial impact on adult longfin smelt migration and spawning.

Eggs and Larvae

In the San Francisco Estuary, most longfin smelt larvae hatch between December and May, and rarely outside of this range (Baxter 1999). Longfin smelt larvae are most abundant in the water column usually from January through April (Bureau of Reclamation 2008). Larval longfin smelt rear in low salinity to brackish water (2–12 ppt; Grimaldo et al. 2017) and in tidal wetlands of San Pablo Bay (Sonoma Creek, Napa River, and Petaluma River) and south San Francisco Bay (Alviso Marsh Complex and salt pond restoration areas) (Hobbs et al. 2015, Lewis et al. 2020). The spatial distribution of these larvae reflects the year-to-year variation in freshwater outflow which affects the geographic location of the low-salinity zone during the winter and spring (Dege and Brown 2004, Grimaldo et al. 2020). During high outflow years, the low salinity zone can extend into San Pablo Bay. Within the low-salinity zone and adjacent waters, larvae have been commonly collected in both littoral (nearshore) and pelagic (offshore) habitats.

Potential Changes to Longfin Smelt from Seasonal Operations

<u>CalSim 3 Modeled X2 Position</u>

The position of X2 under Alternative 3 ranged from similar to further seaward when compared to the No Action Alternative (Table O-252) during the larval longfin smelt period, varying 0-5 km from the No Action Alternative, likely having negligible to beneficial impacts on larval longfin smelt in the spring.

<u>Zooplankton CPUE-Outflow Analysis</u>

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for 5 zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 3, when compared to the No Action Alternative, cladocearns (except *Daphnia*) had the largest expected CPUE increase of 20% during the critically dry water year type and the smallest expected CPUE increase of 10% during the wet water year type. *E. affinis* adults had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Harpacticoids had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Other calanoid copepod adults had the largest expected CPUE increase of 15% during the critically dry water year type and the smallest expected CPUE increase of 9% during the wet water year type. Other calanoid copepod copepodites had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 6% during the wet water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 3 are generally higher than the No Action Alternative for spring months and water year types (Table O-254) resulting in higher zooplankton CPUE.

<u>Summary</u>

Alternative 3 relative to the No Action Alternative is expected to have beneficial impacts on longfin smelt larvae due to differences in flow. Compared to the No Action Alternative, CPUE of longfin smelt prey species under Alternative 3 is expected to increase during the spring. The

position of X2 under Alternative 3 ranged from similar to further seaward when compared to the No Action Alternative likely resulting in negligible to beneficial impacts on larval longfin smelt.

Potential Changes to Entrainment of Longfin Smelt

Particle Tracking Model (PTM)

Inflow Bins.

Depending on inflow conditions, an average of 0 to 7% of SO particles and 0 to 6% of NB particles injected within the Sacramento River region would be entrained at export facilities under Alternative 3, compared to 1 to 16% (SO) and 1 to 13% (NB) particles under the No Action Alternative. Regardless of inflow conditions, the average percentage of particles entrained at exports under Alternative 3 was always lower than under the No Action Alternative, ranging from -27% under "hihi" conditions to -96% under "medhi" conditions for both SO and NB particles.

Depending on inflow conditions, an average of 0 to 2% (SO) or 0 to 1% (NB) of particles injected within the Western Delta region would be entrained at export facilities under Alternative 3, compared to 0 to 4% (SO) and 0 to 3% (NB) under the No Action Alternative. Regardless of inflow conditions, the average percentage of particles entrained at exports under Alternative 3 was always lower than under the No Action Alternative, ranging from -27% under "lomed" conditions (SO) and -1% under "hihi" conditions (NB) to -96% (SO) and -99% (NB) under "medhi" conditions.

Depending on inflow conditions, an average of 0 to 3% (SO) or 0 to 2% (NB) of particles injected within the Yolo Bypass region would be entrained at export facilities under Alternative 3, compared to 0 to 8% (SO) and 0 to 5% (NB), under the No Action Alternative. Regardless of inflow conditions, the average percentage of particles entrained at exports for Alternative 3 was always lower than for the No Action Alternative, ranging from -31% (SO) and -21% (NB) under "hihi" conditions to -96% (SO) and -97% (NB) under "medhi" conditions.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of inflow conditions, there was a lower average percentage of particles entrained under Alternative 3 compared to the No Action Alternative (-58% to 0% NB and SO).

OMR bins.

Depending on OMR flow conditions, an average of 18 to 72% (SO) or 17 to 71% (NB) of particles injected within the Central Delta region would be entrained at export facilities under Alternative 3, compared to 24 to 81% (SO) and 22 to 79% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 31% lower for both SO and NB particles under Alternative 3 than under the No Action Alternative for the -5000 OMR bin to 26% (SO) and 27% (NB) higher for the -3500 OMR bin.

Depending on OMR flow conditions, an average of 20 to 73% (SO) or 17 to 70% (NB) of particles injected within the Mokelumne River region would be entrained at export facilities under Alternative 3, compared to 23 to 78% (SO) and 24 to 72% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 23% (SO) and 24% (NB) lower under Alternative 3 than under the No Action Alternative for the -5000 OMR bin to 20% higher for the -3500 OMR bin for both SO and NB particles.

Depending on OMR flow conditions, an average of 1 to 11% (SO) or 1 to 9% (NB) of particles injected within the Yolo Bypass region would be entrained at export facilities under Alternative 3, compared to 2 to 16% (SO) and 1 to 13% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 66% lower (SO) and 67% lower (NB) under Alternative 3 than under the No Action Alternative for the -5000 OMR bin to 54% (SO) and 55% (NB) higher for the -3500 OMR bin.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of OMR flow conditions, there was generally little difference between the average percentage of particles entrained under Alternative 3 and under the No Action Alternative (-3 to +1% NB and SO).

Summary

The percentage of particles entrained at exports were generally similar between surface-oriented particles representative of yolk-sac larval longfin smelt and neutrally buoyant particles representative of >10mm larval longfin smelt. For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta) Alternative 3 relative to the No Action Alternative is expected to have a beneficial impact on the entrainment of larval longfin smelt for all inflow groupings. For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), Alternative 3 would generally have a minor positive to similar impact on entrainment of larval longfin smelt compared to the No Action Alternative for all OMR grouping.

Juveniles

Juveniles have been detected throughout the San Francisco Estuary and rarely in some Delta tributaries (Merz et al. 2013). Juveniles gradually move seaward as they grow and as water temperatures increase in the late spring and early summer (Rosenfield and Baxter 2007; Tobias and Baxter 2021). Seasonal patterns in abundance and occurrence in the nearshore ocean suggest that the population is at least partially anadromous (Rosenfield and Baxter 2007; Garwood 2017). The detection of longfin smelt within the estuary throughout the year and geochemical analysis of otoliths suggests longfin smelt in the San Francisco Estuary utilize several life history strategies (Lewis et al. 2019).

Potential Changes to Longfin Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 3 ranged from similar to further seaward when compared to the No Action Alternative (Table O-252) during the juvenile longfin smelt period, varying 0-5 km from the No Action Alternative, likely having negligible to beneficial impacts on juvenile longfin smelt in the summer.

Longfin Smelt Abundance-Outflow Analysis

Juvenile Longfin Smelt abundance as represented by the Fall Midwater Trawl index of abundance is predicted to be higher under Alternative 3 than the No Action Alternative, regardless of water year type (Attachment J.1, *Longfin Smelt Outflow*, Table 3). The extent to which the predicted abundance for Alternative 3 is larger than the No Action Alternative increases incrementally as water year types become more wet, ranging from 19% higher during critically dry water years, to 40% higher during wet water years.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 3, when compared to the No Action Alternative, cladocearns (except *Daphnia*) had the largest expected CPUE increase of 20% during the critically dry water year type and the smallest expected CPUE increase of 10% during the wet water year type. *E. affinis* adults had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Harpacticoids had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 7% during the wet water year type. Other calanoid copepod adults had the largest expected CPUE increase of 15% during the critically dry water year type and the smallest expected CPUE increase of 9% during the wet water year type. Other calanoid copepod copepodites had the largest expected CPUE increase of 11% during the critically dry water year type and the smallest expected CPUE increase of 6% during the wet water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 3 are generally higher than the No Action Alternative for spring months and water year types (Table O-254) resulting in higher zooplankton CPUE.

During the summer months (May to August), the zooplankton-outflow analysis showed no significant relationships between outflow and zooplankton CPUE. Several studies have previously found relationships between abundance of zooplankton taxa and outflow during the summer (e.g. Kimmerer 2002, Kimmerer et al. 2018) while other studies have found mixed effects (Frantzich et al. 2021) or no effects (Sommer et al. 2020) of increased flow on zooplankton abundance. Evaluating possible benefits of increased outflow and flow pulses during summer may be difficult given sampling frequency and the effect size of increases to zooplankton abundances (Brandon et al. 2021).

Summary

Alternative 3 relative to the No Action Alternative is expected to have beneficial impacts on juvenile longfin smelt due to differences in flow. Juvenile longfin smelt abundance as represented by the Fall Midwater Trawl index of abundance is predicted to be higher under Alternative 3 than it is for the No Action Alternative. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to increase under Alternative 3 during the spring. The position of X2 under Alternative 3 ranged from similar to further seaward when compared to the No Action Alternative likely resulting in negligible to beneficial impacts on juvenile longfin smelt.

Potential Changes to Entrainment of Longfin Smelt

Longfin Smelt Outflow Entrainment

The regression from Grimaldo et al. (2009) between April-May juvenile longfin smelt entrainment and Old and Middle River flows was used to assess potential differences in salvage between modeled alternatives. The analysis does not account for changes in operations since the USFWS 2008 and NMFS 2009 Biological Opinion, changes in population size over time, turbidity, juvenile behavior, and geographic shifts in distribution during higher outflow years.

Changes in OMR flows under Alternative 3 compared with the No Action Alternative may have an impact on LFS salvage. Compared to the No Action Alternative, predicted salvage decreases ranged from 47% during the critically dry water year type to 92% during the wet water year type. Alternative 3 had the least negative mean April-May OMR values during drier water year types and positive OMR flows during wetter years compared to the No Action Alternative and therefore lowest predicted salvage. Overall modeling for Alternative 3 suggests that longfin smelt salvage would decrease substantially when compared to the No Action Alternative. (Attachment I.4, *Longfin Smelt Salvage-OMR Relationship*).

Summary

Alternative 3 relative to the No Action Alternative is expected to have a substantial beneficial impact on the entrainment of longfin smelt due to differences in flow. Overall modeling for Alternative 3 suggests that longfin smelt salvage would decrease substantially when compared to the No Action Alternative.

O.6.14 Fall-run and Late Fall-run Chinook Salmon ESU

O.6.14.1 Sacramento River

Spawning and Egg/Alevin Incubation

Fall-run Chinook salmon typically spawn in the Sacramento River, primarily between Keswick Dam and RBDD from October through December, with incubation occurring from October through April. Peak spawning time for late fall-run Chinook salmon generally is from January through April (National Marine Fisheries Service 2009a), with incubation typically lasting for approximately two to four months between April and June (Moyle 2002). See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 3, differences in mean spawning WUA are higher in wet, above normal, and critically dry water year types, and lower in below normal and dry water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 3 and the No Action Alternative is a 2.5% increase in above normal water years. The largest reduction in estimated spawning habitat is a -2.5% decrease in below normal water year types.

The monthly median value of spawning WUA under Alternative 3 is slightly higher than the No Action Alternative September through December (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are relatively similar in September and October, and slightly lower in November and December. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently highest in December when compared to other spawning months (Table O-248). This results in lower spawning WUA results because the fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of the spawning habitat analysis based on CalSim 3 simulated flows suggest that Alternative 3 may have a minor (less than 3%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. Out of the four months of potential fall-run Chinook salmon spawning, September and October have the highest estimated spawning WUA across all alternatives.

Fall-run Chinook Salmon: Redd Dewatering Analysis

Fall-run Chinook salmon mean redd dewatering potential under Alternative 3 increases from drier to wetter water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). Most egg incubation of fall-run occurs during fall and winter, when periodic storms and high runoff in wetter years result in increased flow fluctuations, increasing risk of redd dewatering. In drier winters, flow fluctuations are reduced and fewer redds are dewatered. Differences in mean redd dewatering potential between Alternative 3 and the No Action Alternative are large for most water year types, including reductions of 9.6%, 11.2%, and 7.3% for wet, above normal, and below normal water year types, respectively, and an increase of 12.7% for critically dry years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The apparent magnitude of these relative differences may be misleading because all absolute differences are less than 2%.

Overall, the results indicate that fall-run Chinook salmon redd dewatering potential under Alternative 3 is lower or higher than that under the No Action Alternative, depending on the water year type.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 235 for Keswick Dam and Table 236 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 238 for Keswick Dam and Table 239 for RBDD. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during December through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 241 for Keswick Dam and Table 242 for RBDD.

Results for the three analyses are summarized in Table O-74. Table O-74, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 42.1°F to 55°F spawning initiation range analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at both Keswick Dam and RBDD (Table O-74). There were zero and one combinations (0% and 5.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there was one combination (5.0%) with favorable results at both Keswick Dam and RBDD and no combinations (0%) with unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero and one combinations (0% and 5.0%, respectively) with favorable results at Keswick Dam and RBDD, respectively and no combination (0%) with unfavorable results at both locations. These results suggest that there would be negligible positive and negative effects of Alternative 3 on fall-run Chinook salmon spawning and egg/alevin incubation.

Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on redd dewatering from sudden drops in flow. However, redd surveys occur during the pulse flow period and redd dewatering has not been observed.

Fall-run Chinook Salmon: Summary

The change in seasonal operations in the Sacramento River between Alternative 3 and the No Action Alternative are expected to have minor impacts on fall-run Chinook salmon spawning habitat and incubation. Under Alternative 3, changes in flows cause minor increases and decreases in spawning habitat area in all water year types. Changes in flows would result largely in minor decreases of redd dewatering potential for fall-run Chinook salmon compared to the No Action Alternative. There may be redd dewatering following spring pulse flow events, though this has not been observed during redd surveys. Water temperatures under Alternative 3 would result in similar conditions to the No Action Alternative for spawning initiation, egg incubation and fry emergence, and pathogen virulence.

Late Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 3, differences in mean spawning WUA are lower in all water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). There are no increases in mean estimated spawning habitat between Alternative 3 and the No Action Alternative. The largest reduction in estimated spawning habitat is a -5.9% decrease in above normal water year types.

The monthly median values of spawning WUA under Alternative 3 are similar to the No Action Alternative throughout the three spawning months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are also relatively similar across all three spawning months. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are highest in February but all three months are above 8,000 cfs (Table O-248). This results in spawning WUA results that are approximately the same

across all three months because the late fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) peak at relatively low flows (approximately 3,000 to 6,000 cfs).

Overall, the spawning habitat analysis based on CalSim 3 simulated flows indicate that Alternative 3 may have a minor (5.9%) decrease in estimated spawning habitat during above normal water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. The three months of potential late fall-run Chinook salmon spawning have similar estimated spawning WUA across all alternatives.

Late Fall-run Chinook Salmon: Redd Dewatering Analysis

The results for Alternative 3 show substantial increases in percentage of late fall-run Chinook salmon redds dewatered with water year type, varying from high redd dewatering in wet water years to low redd dewatering in critically dry water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation reflects flow conditions for the winter and spring months when late fall-run Chinook salmon spawning and incubation occurs (Table O-248). During wet winters and springs, periodic storms and high runoff increase flow and flow variability, which tends to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. Mean redd dewatering potential increases from Alternative 3 to the No Action Alternative under all water year types, and several of the increases are large (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The largest increase is 35.5% for the redd dewatering means in critically dry years. Other large increases are 10.2% and 13.1% for below normal and above normal water years, respectively. Note that the 35.5% increase for critically dry years represents an absolute difference in redd dewatering of 0.9%.

Overall, the results indicate that redd dewatering potential under would be higher Alternative 3 then under the No Action Alternative.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 267 for Keswick Dam and Table 268 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 270 for Keswick Dam and Table 271 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 273 for Keswick Dam and Table 274 for below Clear Creek.

Results for the three analyses are summarized in Table O-75. Table O-75, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 42.1°F to 55°F spawning initiation range analysis, there were three and two month-water year type combinations (15.0% and 10.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and Clear Creek, respectively (Table O-75). There were no combinations (0%) with unfavorable results at either location. For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four and seven combinations (20.0% and 35.0%, respectively) with favorable results at Keswick Dam and Clear Creek, respectively. There were no combinations (0%) with unfavorable results at both locations. These results suggest that there would be positive water temperature effects of Alternative 3 on late fall-run Chinook salmon spawning initiation, egg incubation, and fry emergence, and negligible negative effects to these life stages.

Late Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on spawning behavior and redd dewatering from sudden drops in flow. However, redd surveys occur during the pulse flow period and redd dewatering has not been observed.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in the Sacramento River between Alternative 3 and the No Action Alternative are expected to have minor impact on fall-run Chinook salmon spawning habitat and incubation. Under Alternative 3, changes in flows may cause a minor decrease in spawning habitat area in above normal water years, but redd dewatering would experience an minor increase to the conditions under the No Action Alternative. Water temperatures would be more favorable for spawning initiation, and egg incubation and fry emergence, but similar for pathogen virulence compared to the No Action Alternative. There may be changes to spawning behavior and redd dewatering with spring pulse flow events, but redd dewatering has not been observed during the pulse flow period. Water temperatures are expected to have minimal impacts on late fall-run Chinook salmon spawning and incubation or the frequency of pathogen virulence under Alternative 3.

Juvenile Rearing and Emigration

The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, mostly between January through June. Late fall-run Chinook salmon juveniles typically enter the ocean after 7 to 13 months of rearing in freshwater, generally between October and February. See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under Alternative 3, mean fry rearing WUA decreases in all water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). There are no anticipated increases in mean fry rearing WUA in comparison to the No Action Alternative. The largest reduction in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 2.3% decrease in above normal water year types.

The monthly median value of fry rearing WUA under Alternative 3 has a 5% reduction in February and December below the No Action Alternative but is similar throughout the other fry rearing months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The results during January and March show little variation in the third quartile of the WUA distributions. This occurs because the fry rearing WUA curves peak at the lowest flows encountered in the river (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and Keswick Dam flow releases are frequently low during these months in critically dry years when Shasta Reservoir is operated to rebuild storage volume (Table O-248). The first quartile is much wider because a greater range of flows affect the fry rearing WUA values below the median.

The results of the fall-run Chinook salmon fry rearing habitat analysis suggest that Alternative 3 in comparison to the No Action Alternative may have a minor (up to 2.3%) decrease in estimated fry rearing habitat across all water year types and the greatest reduction in estimated habitat may occur in February and December (5%) in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Fall-run Chinook Salmon: Juvenile Rearing Habitat Analysis

Under Alternative 3, mean juvenile rearing WUA increases in below normal, dry, and critically dry water year types and reductions in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 3.5% increase in critically dry water year types. The largest reduction in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 1.6% decrease in wet water year types.

The monthly median value of juvenile rearing WUA under Alternative 3 is 7% higher than the No Action Alternative in June but similar February through May (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under the modeled alternatives are similar across the months of February and March, and gradually decrease until the lowest estimated values in June. As discussed previously for fry rearing WUA, the high WUA values with low variability in the third quartile for February and March result from the peaking of the WUA curve at the lowest flows and frequent low Keswick Dam flow releases during these months to build Shasta Reservoir storage (Table O-248). The wide range of values in the first quartile of these months reflects the high frequency and variability of higher flows in these wet months. The lowest juvenile rearing WUA values in June result from releases in the summer months above 10,000 cfs and estimated peak juvenile rearing at flows below 5,000 cfs.

The results of the fall-run Chinook salmon juvenile rearing habitat analysis suggest that Alternative 3 in comparison to the No Action Alternative may have a minor (less than 4%) increases and/or decrease in estimated juvenile rearing habitat across all water year types and the greatest increase in estimated habitat may occur in June (7%) in the mainstem upper Sacramento River.

Fall-run Chinook Salmon: Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Alternative 3 shows a substantial but variable increase in stranding of fall-run Chinook salmon fry from critically dry to wet water year types, with a minor reduction in stranding from dry to below normal water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Fall-run fry rearing occurs primarily during winter and early spring. Alternative 3 shows the highest stranding in February and similar stranding levels in December, January, and March (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher mean stranding levels for fall-run fry during February and wet water years likely results from periodic storms and high runoff that produce increased variability of flow. Mean fall-run fry stranding under Alternative 3 is similar to that under the No Action Alternative in most water year types but is 12.5% higher in above normal water years and 6.0% lower in critically dry water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Other differences are less than 4%.

Overall, fall-run juvenile stranding for fry is similar under Alternative 3 to that under the No Action Alternative, but the Alternative 3 has higher stranding in above normal water years and lower stranding in critically dry years.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 247 for Keswick Dam, Table 248 for Red Bluff Diversion Dam, and Table 249 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 251 for Keswick Dam, Table 251 for Red Bluff Diversion Dam, and Table 253 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 255 for Keswick Dam, Table 256 for Red Bluff Diversion Dam, and Table 257 for Hamilton City.

Results for the three analyses are summarized in Table O-76. Table O-76, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to one month-water year type combinations (0% to 5.0% of total combinations during the period) with favorable results depending on location (Table O-76). There were zero to six combinations (0% to 30.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations with either favorable or unfavorable results For the 59.9°F juvenile pathogen virulence threshold, there were zero to five combinations (0% to 25.0%) with favorable results depending on location. There would be zero to two combinations (0% to 10.0%) with unfavorable results depending on location. These

results suggest that there would be positive and negative water temperature-related effects of Alternative 3 on fall-run Chinook salmon juvenile rearing and emigration.

Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

Fall-run Chinook Salmon: Summary

Under Alternative 3, differences in seasonal operations in the Sacramento River are expected to have largely minor impacts on fall-run Chinook salmon fry and juvenile rearing habitat and behavior. There would be minor decreases in WUA for fall-run Chinook salmon fry rearing habitat in all water year types relative to the No Action Alternative, while juvenile rearing habitat would have minor increases and decreases in all water year types. Fry stranding in the Sacramento River would be similar to stranding of fall-run Chinook salmon except some increases in fry stranding in above normal water year types. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. Water temperatures in the Sacramento River would result in more unfavorable conditions below Keswick Dam for growth, smoltification and predation, but more favorable conditions for fall-run Chinook salmon juveniles, particularly at RBDD, regarding pathogen virulence.

Late Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under Alternative 3, mean fry rearing WUA increase in below normal, dry, and critically dry water year types and decrease in all other water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 5.6% increase in critically dry water year types. The largest reduction in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 1.0% decrease in wet water year types.

The monthly median value of fry rearing WUA under Alternative 3 is 5% higher than the No Action Alternative in April but similar during the other fry rearing months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis s*). The fry rearing WUA median values under the modeled alternatives are similar across the months of May and June, and highest in March. The lower fry rearing WUA values in May and June result from releases in the summer months above 7,000 cfs (Table O-248) and estimated peak fry rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the late fall-run Chinook salmon fry rearing habitat analysis suggest that Alternative 3 in comparison to the No Action Alternative may have a minor (less than 6%) increase and/or decrease in estimated fry rearing habitat across all water year types and the greatest increase in estimated habitat may occur in April (5%) in the mainstem upper Sacramento River.

Late Fall-run Chinook Salmon: Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Mean stranding of late fall-run Chinook salmon fry under Alternative 3 shows minor and inconsistent variation with water year type; wet years have the highest stranding and dry years the lowest, while stranding is similar in critically dry, below normal, and above normal water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Late fall-run Chinook salmon fry rearing occurs primarily during spring. Alternative 3 shows the highest median stranding in March, the lowest stranding in May, and similar stranding in April and June (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Mean fry stranding of late fall-run Chinook salmon is greater for all water year types under Alternative 3 than under the No Action Alternative. The increases range from 5.0% for dry water years to 29.0% for above normal water years. The increase for critically dry water years, 15.3%, is also notable (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, late fall-run Chinook salmon juvenile stranding for fry is higher under Alternative 3 as compared to the No Action Alternative for all water year types and is much higher for above normal and critically dry water years.

Late Fall-run Chinook Salmon: Juvenile Rearing Habitat Analysis

Under Alternative 3, mean juvenile rearing WUA constitute increases in wet, above normal, below normal, and critically dry water year types and a reduction in dry water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 3 and the No Action Alternative is a 4.4% increase in critically dry water year types. The largest reduction in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 1.2% decrease in dry water year types.

The monthly median value of juvenile rearing WUA under Alternative 3 is 7% higher than the No Action Alternative in June and 6% lower in August (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). During the juvenile rearing period, the median WUA values steadily decline from May to the lowest median WUA values in July. The lower juvenile rearing WUA values in June and July result from releases in the summer months above 7,000 cfs (Table O-248) and estimated peak juvenile rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the late fall-run Chinook salmon juvenile rearing habitat analysis suggest that Alternative 3 in comparison to the No Action Alternative may have a minor (less than 5%) increase and/or decrease in estimated juvenile rearing habitat across all water year types. The greatest increase in estimated habitat may occur in June (7%) and the greatest decrease in estimated habitat may occur in August (6%) in the mainstem upper Sacramento River.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during April through February are presented in Attachment L.1, *Sacramento River*

Water Temperature Analysis, Table 279 for Keswick Dam, Table 280 for Red Bluff Diversion Dam, and Table 281 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 283for Keswick Dam, Table 284 for Red Bluff Diversion Dam, and Table 285 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 287 for Keswick Dam, Table 288 for Red Bluff Diversion Dam, and Table 289 for Hamilton City.

Results for the three analyses are summarized in Table O-77. Table O-77, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to three month-water year type combinations (0% to 5.5% of total combinations during the period) with favorable results depending on location (Table O-77). There were zero to eight combinations (0% to 14.5%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were one to 11 combinations (1.8% to 20.0%) with favorable results depending on location. There would be zero to three combinations (0% to 5.5%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 3 on late fall-run Chinook salmon juvenile rearing and emigration.

Late Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

Late Fall-run Chinook Salmon: Summary

Under Alternative 3, differences in seasonal operations in the Sacramento River are expected to have largely minor impacts on late fall-run Chinook salmon fry and juvenile rearing habitat and behavior. There would be minor increases and decreases in WUA for fall-run Chinook salmon fry and juvenile rearing habitat in all water year types relative to the No Action Alternative. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. Late fall-run Chinook salmon fry stranding in the Sacramento River would be higher under Alternative 3 for all water year types, with higher stranding risks under above normal and critically dry water years. Water temperatures in the Sacramento River under Alternative 3 would result in more unfavorable conditions below Keswick Dam for growth, smoltification and predation, but more favorable conditions at Hamilton City. There would be more favorable conditions for juvenile late fall-run Chinook salmon at Keswick Dam and RBDD with regards to pathogen virulence, but there are more unfavorable conditions at Hamilton City.

Adult Upstream Migration and Holding

Fall-run Chinook salmon migrate upstream past RBDD on the Sacramento River from July to December, and late fall-run Chinook salmon migrate upstream past RBDD from October through December (National Marine Fisheries Service 2009a). Adult late fall-run Chinook salmon typically hold in the river for one to three months before spawning, while fall-run Chinook salmon generally spawn shortly after entering freshwater. See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

During the July through December period of fall-run and late fall-run Chinook salmon adult migration and holding, the mean monthly flows under Alternative 3 at Sacramento River below Keswick Dam, below RBDD, Hamilton City, and Wilkins Slough would vary from less than to greater than flows under the No Action Alternative. Flows in July at all locations are mostly lower (4 to 23% reduction in flows) than under the No Action Alternative. An exception to this is in dry and critically dry water years when flows have minor to moderate increases (1% to 15%). Flows in August are typically lower in wet and above normal water years (-4% to -9%), but typically increase in flows in below normal, dry and critically dry water years (6% to 43%). September flows, except in below normal water years, are generally lower (-3% to 14%) under Alternative 3 compared to the No Action Alternative. Generally, flows in October and November are similar, but with the greatest increases in flow occurring in dry and critically dry water years (1% to 19%). Except at Wilkins Slough, average flows in December typically increase at minor to moderate levels (1% to 23%), with average flows for all water years combined increased between 4% and 8%. Wet water years at all locations are mostly lower than flows under the No Action Alternative, however, there is a negligible increase in flows in December at RBDD and Hamilton City.

The average monthly flows across all water year types under Alternative 3 between July and December would be greater than 8,000 cfs below Keswick Dam, 9,250 cfs below RBDD, nearly 8,800 cfs at Hamilton City, and nearly 6,300 cfs at Wilkins Slough (Table O-248, Table O-249, Table O-251, Table O-250). Flows at in the Sacramento River under Alternative 3 would be high enough (> 3,250 cfs) to allow upstream passage.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 227 for Keswick Dam, Table 228 for Red Bluff Diversion Dam, and Table 229 for Hamilton City. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 231 for Keswick Dam, Table 232 for Red Bluff Diversion Dam, and Table 233 for Hamilton City.

Results are summarized in Table O-78. Table O-78, as described in Section O.4.8.1 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 37.9°F to 68°F successful adult migration range analysis, there were zero to two month-water year type combinations (0% to 6.7% of total combinations during the period) with favorable results depending on location (Table O-78). There were no combinations (0%) with unfavorable results at all locations. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to six combinations (0% to 20.0%) with favorable results and zero to two combinations (0% to 6.7%) with unfavorable results depending on location. These results suggest that there would be positive effects of Alternative 3 on water temperature conditions for fall-run Chinook salmon in the Sacramento River.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 259 for Keswick Dam, Table 260 for Red Bluff Diversion Dam, and Table 261 for Hamilton City. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 262 for Keswick Dam, Table 263 for Red Bluff Diversion Dam, and Table 264 for Hamilton City.

Results are summarized in Table O-79. Table O-79 as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 37.9°F to 68°F successful adult migration range analysis, there were zero to two month-water year type combinations (0% to 5.0% of total combinations during the period) with favorable results depending on location (Table O-79). There were no combinations (0%) with unfavorable results at all locations. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to five month-water year type combinations (0% to 12.5%) with favorable results and zero to one month-water year type combinations (0% to 2.5%) with unfavorable results depending on location. These results suggest that there would be positive effects of Alternative 3 on water temperature conditions for late fall-run Chinook salmon adult migration and holding in the Sacramento River.

Sacramento River Pulse Flows

Fall-run and late fall-run adult migration is outside the spring pulse flow period.

Summary

Under Alternative 3, fall-run and late fall-run Chinook salmon would be impacted by differences in seasonal operations in the Sacramento River. Flows in the Sacramento River would result in both increases and decreases, affecting adult migration and holding conditions. Conditions for adult fall-run and late fall-run Chinook salmon successful migration are expected to be similar to

the No Action Alternative, but with some more favorable conditions at Hamilton City. Below Keswick Dam and RBDD, fall-run and late fall-run Chinook salmon migrating adults would be exposed to more favorable conditions with respect to pathogen virulence. Migrating adult fall-run and late fall-run Chinook salmon would be experience both adverse and beneficial impacts under Alternative 3 compared to the No Action Alternative.

O.6.14.2 Clear Creek

Spawning and Egg Incubation

Fall-run Chinook salmon typically spawn in Clear Creek from late September through early December, (Earley et al. 2013). Fall-run typically emerge from the gravel in December through March. Timing of peak late-fall spawning in the Sacramento River, January through April, was used as a proxy for Clear Creek. Late fall-run incubation and emergence is estimated to occur from March through June.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 3, mean spawning WUA increases in below normal and critically dry water year types and decreases in all other water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat is a 13.3% increase in critically dry water year types. The largest reduction in estimated spawning habitat is a 0.5% decrease in dry, wet, and above normal water year types.

The mean values of spawning WUA by month are lower in October and higher in November and December under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). December is expected to have the highest spawning WUA values under Alternative 3 throughout the spawning period.

The spawning habitat analysis suggests that Alternative 3 may have a beneficial effect (up to a 13.3% increase) in fall-run Chinook salmon estimated spawning habitat in Clear Creek in critically dry years when compared to the No Action Alternative, and a beneficial effect in below normal years, and a negligible effect in all other water year types.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 237 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 240 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during December through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 243 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-80. Table O-80, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-80). For the 59.9°F pathogen virulence threshold, there were zero (0%) combinations with either favorable or unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero (0%) combinations with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on fall-run Chinook salmon spawning and egg incubation in Clear Creek.

Fall-run Chinook Salmon: Summary

Overall, there may be a beneficial impact from seasonal operations on fall-run Chinook salmon spawning and egg incubation in Clear Creek based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows may have a beneficial impact on spawning habitat with an increase in critically dry and below normal years, and a negligible impact in all other water year types with similar impacts to water temperature conditions.

Late Fall-run Chinook Salmon: CalSim 3 Flows

For the period of late-fall run Chinook salmon spawning and egg incubation (January through June), seasonal operations may result in both negative and positive impacts below Whiskeytown Dam under Alternative 3 compared to the No Action Alternative. Average annual flow during this period would substantially increase in January (35%), March (33%), April (20%) and May (41), but have a minor decrease in February (6%), and a substantial decrease in June (28%) (Table O-257). In February, flows would decrease in wet, above normal, and below normal water years but increase during dry and critically dry years.

Using peak spawning flows of 300-350 cfs from the fall-run Chinook salmon WUA curves as a proxy for potential late-fall-run Chinook salmon spawning habitat, changes under Alternative 3 suggest that, when averaged across all water year types, flows would increase favorable spawning habitat except in June. However, flows do not exceed the 300 cfs peak spawning flows except in February, which does experience a slight decrease in average flows of 6% compared to the No Action Alternative.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperatures outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 282 for Clear Creek below Whiskeytown. Full results of the analysis assessing the percent of months with water temperatures above the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water*

Temperature Analysis, Table 286 for Clear Creek below Whiskeytown. Full results of the analysis assessing the percent of months with water temperatures above the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 290 for Clear Creek below Whiskeytown.

Results for the three analyses are summarized in Table O-81. Table O-81, described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown (Table O-81). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown. For the 59.9°F juvenile pathogen virulence threshold, there were no month-water year type combinations (0%) with either favorable or unfavorable results below Whiskeytown. These results suggest that there would be water temperature-related negligible effects of Alternative 3 on late fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Juvenile Rearing and Emigration

The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, mostly between January through June. Late fall-run Chinook salmon juveniles typically enter the ocean after 7 to 13 months of rearing in freshwater, generally between October and February (Moyle 2002).

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

<u>Fall-run Chinook Salmon: Fry Rearing Habitat Analysis</u>

Under Alternative 3, mean fry rearing WUA decreases in all water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean fry rearing WUA under Alternative 3 in comparison to the No Action Alternative. The greatest reduction in estimated fry rearing habitat is a 2.6% decrease in dry water year types under Alternative 3 in comparison to the No Action Alternative.

The mean values of fry rearing WUA are similar across all months under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*).

The results of the fry rearing habitat analysis suggest that Alternative 3 compared to the No Action Alternative may have a minor adverse effect (less than 3% decrease) in estimated fall-run Chinook salmon fry rearing habitat across all water year types in Clear Creek.

<u>Fall-run Chinook Salmon: Juvenile Rearing Habitat Analyses</u>

Under Alternative 3, mean juvenile rearing WUA decreases in all water year types compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 3 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 3 and the No Action Alternative is a 6.2% decrease in critically dry water year types.

On average across all water year types, there is a 4.1% reduction in estimated juvenile rearing habitat under Alternative 3.

The mean values of juvenile rearing WUA by month are lower June through September and higher in May under Alternative 3 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). May is expected to have the highest juvenile rearing WUA values under Alternative 3 throughout the juvenile rearing period.

The results of the juvenile rearing habitat analysis suggests that Alternative 3 compared to the No Action Alternative may have a minor adverse effect (up to 6.2% decrease) in fall-run Chinook salmon juvenile rearing habitat across all water year types.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 250 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 254 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 258 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-82. Table O-82, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-82). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F juvenile pathogen virulence threshold, there were no month-water year type combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be water temperature-related negligible effects of Alternative 3 on fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Fall-run Chinook Salmon: Summary

There may be minor adverse impacts of seasonal operations on fall-run Chinook salmon fry rearing and emigration habitat in Clear Creek based on analyses of simulated flows and water temperature under Alternative 3 in comparison with the No Action Alternative. Under Alternative 3, changes in flows are expected to have a minor decrease (less than 3%) in estimated fall-run Chinook salmon fry rearing habitat across all water year types in Clear Creek. Additionally, the results of the juvenile rearing habitat analysis indicates that Alternative 3 in comparison to the

No Action Alternative may have up to 6.2% decrease in habitat. Potential water temperature-related impacts (growth, smoltification, predation, and pathogen virulence) results suggest that there would be negligible impacts of Alternative 3 on fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Late Fall-run Chinook Salmon: CalSim 3 Flows

For the period late-fall juvenile rearing and emigration (October through February), there would be both negative and beneficial impacts below Whiskeytown Dam under Alternative 3 compared to the No Action Alternative. Average annual flow released would increase by minor level in November and substantial amounts in December and January (Table O-257). Flows would substantially decrease in October and have a minor decrease in February (Table O-257).

The largest flow decreases in October and February occur in wet, above normal, and below normal water years, though October also shows substantial decreased flows in dry water years. December and January experience substantial increased flows in all water year types, while October, November, and February primarily experience substantial increased flows in critically dry water years. There would generally be a substantial increase in fry and juvenile rearing habitat available for late fall-run Chinook salmon caused by increased flows in Clear Creek in November through January, but a minor to substantial decrease in fry and juvenile rearing habitat in October and February caused by decreased flows.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 282 for Clear Creek below Whiskeytown. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 286 for Clear Creek below Whiskeytown. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 290 for Clear Creek below Whiskeytown.

Results for the three analyses are summarized in Table O-83. Table O-83, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown (Table O-83). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown. For the 59.9°F juvenile pathogen virulence threshold, there were no month-water year type combinations (0%) with either favorable or unfavorable results below Whiskeytown. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on late fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 3 and the No Action Alternative is expected to have both positive and negative impacts on late fall-run Chinook salmon rearing and emigration. Increased flows in November through January would provide substantially beneficial conditions for late fall-run Chinook salmon rearing and emigration, but decreased flows in October and February would result in adverse impacts. Under Alternative 3, there would be negligible water temperature-related impacts on late fall-run Chinook salmon rearing and emigration in Clear Creek compared to the No Action Alternative.

Adult Upstream Migration and Holding

Fall-run Chinook salmon may arrive at Clear Creek before spawning from July through early December. Adult late fall-run Chinook salmon migrate and arrive slightly later and do not need to hold and mature before spawning from November into January.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: CalSim 3 Flows

For the period of fall and late-fall adult migration and holding (July through January), there would be both negative and beneficial impacts below Whiskeytown Dam under Alternative 3 compared to the No Action Alternative. Average flow released would increase November through January and decrease July through October. The exception is during a critically dry water year during October with an increase of 20% (Table O-257). The largest decrease under Alternative 3 compared to the No Action Alternative occur July and August. There would be a substantial reduction in suitable adult migration conditions for adult fall-run Chinook salmon as a result of flows in Clear Creek.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 230 for Clear Creek below Whiskeytown Dam. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 234 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-84. Table O-84, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 37.9°F to 68°F successful adult migration range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-84). For the 59.9°F adult pathogen virulence threshold, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown

Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on fall-run Chinook salmon adult upstream migration and holding in Clear Creek.

Fall-run Chinook Salmon: Summary

Overall, there may be both moderate negative and beneficial impacts of seasonal operations on fall-run Chinook salmon adult upstream migration and holding in Clear Creek based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows may decrease during the months of July through October and increase in November and January. Water temperature results suggest that there would be negligible impacts of Alternative 3 on fall-run Chinook salmon adult upstream migration and pathogen virulence in Clear Creek.

Late Fall-run Chinook Salmon: CalSim 3 Flows

During the periods of late-fall run Chinook salmon adult migration (November through January), flows would be increased by 23% on average among all water year types when compared to the No Action Alternative. The largest increase is in January with a 35% increase in average flows (222 cfs to 299 cfs). There would also be an increase of 31% in November during critically dry years providing an additional beneficial impact to late fall-run Chinook salmon adult migration and holding (Table O-257).

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature above the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 262 for Clear Creek below Whiskeytown Dam. Full results of the percent of months with water temperature outside the 59.9°F adult pathogen virulence threshold analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 266 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-85. Table O-85, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 37.9°F to 68°F successful adult migration range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-85). For the 59.9°F adult pathogen virulence threshold, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on late fall-run Chinook salmon adult upstream migration and holding in Clear Creek.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 3 and the No Action Alternative is expected to have moderate to substantial benefits adult fall-run Chinook salmon upstream migration and holding. Under Alternative 3, flows would be increased from November through January so there may be a beneficial impact on late-fall-run Chinook salmon adult migration in Clear Creek. Water temperature results suggest that there would be negligible water temperature-related effects of Alternative 3 on late fall-run Chinook salmon adult upstream migration and holding in Clear Creek.

O.6.14.3 Lower American River

Spawning and Egg Incubation

Spawning occurs from about mid-October through early February, with peak spawning from mid-October through December. Chinook salmon spawning occurs within an 18-mile stretch from Paradise Beach to Nimbus Dam; however, most spawning occurs in the uppermost 3 miles (California Department of Fish and Wildlife 2012a). Chinook salmon egg and alevin incubation occurs in the lower American River from about mid-October through April. There is high variability from year to year; however, most incubation occurs from about mid-October through February.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Spawning Habitat—Flow Analysis

Under Alternative 3, fall-run Chinook salmon mean spawning WUA varies among water year types, with no evident trend (Attachment M.3, *American River Weighted Usable Area Analysis*). The highest means are for above normal and below normal water year types and the lowest is for wet water years. Mean spawning WUA differs little between Alternative 3 and the No Action Alternative for all water year types, ranging from 2.5% lower for above normal water year types to 1.4% higher for dry water years (Attachment M.3, *American River Weighted Usable Area Analysis*). For the individual months of the fall-run spawning season, estimated median spawning WUA under Alternative 3 is similar to than the No Action Alternative October and November, but is moderately higher in December (Attachment M.3, *American River Weighted Usable Area Analysis*). October has a higher median spawning WUA than November of December because flows, on average, are lower in October (Table O-259). The fall-run spawning WUA curve (Attachment M.3, *American River Weighted Usable Area Analysis*) peaks at relatively low flows (below 3,000 cfs).

As noted previously, the lower American River WUA curve peaks at about 2,000 cfs (Attachment M.3, *American River Weighted Usable Area Analysis*) and flows under Alternative 3 are consistently well above this level in the wetter water years. Overall, fall-run spawning WUA is similar under Alternative 3 to that under the No Action Alternative.

Redd Dewatering

The results of the analysis for fall-run Chinook salmon under Alternative 3 indicate that mean redd dewatering potential is greatest in wet water years and lowest in critically dry years (Attachment M.1, *American River Redd Dewatering Analysis*). The higher redd dewatering potential in wetter years reflects a greater frequency of large flow fluctuations in those water year types. Redd dewatering is similar under Alternative 3 and the No Action Alternative for most water year types but is much lower (53.1%) for critically dry water years (Attachment M.1, *American River Redd Dewatering Analysis*). It should be noted, however, that the absolute difference in percent of redds dewatered between Alternative 3 and the No Action Alternative in critically dry years is only 2.3%. For the individual months of fall-run spawning in the lower American River, redd dewatering potential increases from October spawning to that in December, reflecting the somewhat higher flows and likelihood of flow fluctuations over this period (Table O-259).

Overall, fall-run Chinook salmon redd dewatering under Alternative 3 is similar to that under No Action Alternative, except for critically dry water years when redd dewatering is much lower on a relative scale, although only modestly lower on an absolute scale.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 42.1°F to 55°F range for spawning initiation during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 63 for Hazel Avenue and Table 64 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult spawning pathogen virulence threshold during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 65 for Hazel Avenue and Table 66 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence during October through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 67 for Hazel Avenue and Table 68 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during October through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 69 for Hazel Avenue and Table 70 for Watt Avenue.

Results for the four analyses are summarized in Table O-86. Table O-86, as described in Section O.4.12.3.1 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 42.1°F to 55°F range for spawning initiation, there were six and zero month-water combinations (17.1 and 0%, respectively) with favorable results at both Hazel and Watt Avenue (Table O-86). There was one month-water combination (2.9%) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for spawning adults, there was zero and one month-water combinations (0% and 2.9%, respectively) with favorable results at both Hazel and Watt Avenue, respectively. There were zero and two combinations (0% and 10.0% respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 42.8°F to 56°F range for egg incubation and fry

emergence analysis, there were two and zero month-water type combinations (6.7% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. Similarly, there were two and zero month-water type combinations (6.7% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold analysis, there were zero to one month-water combinations (0% and 3.3% respectively) with favorable results at Hazel Avenue and Watts Avenue, respectively. There were three and one month-water combinations (10.0% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be positive (2.9% - 3.3% favorable) and negative (2.9% - 11.4% unfavorable) effects of Alternative 3 on fall-run Chinook salmon spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Overall, seasonal operations on fall-run Chinook salmon spawning in the lower American River based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative are similar. Fall-run Chinook salmon spawning habitat area is similar under Alternative 3 to that under the No Action Alternative. For redd dewatering, there are also minimal differences with the exception of a potential slight negative impact in redd dewatering in a critically dry year, but this difference is only 2.4 % larger than the No Action Alternative. Temperature models under Alternative 3, suggest that there could be both beneficial and adverse impacts of Alternative 3 on fall-run Chinook salmon spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue. There would be similar to minor changes to water temperatures for favorable and unfavorable conditions for spawning initiation, pathogen virulence, and egg incubation and fry emergence.

Juvenile Rearing and Emigration

Fall-run Chinook salmon fry emergence occurs from January through mid-April, and juvenile rearing extends from January to about mid-July (Williams 2001). Most Chinook salmon out-migrate from the lower American River as fry from December to July; out-migration peaks in February and March (Snider and Titus 2002; Pacific States Marine Fisheries Commission 2014).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

For the period of juvenile rearing and emigration (December through July), CalSim 3 modeling indicates that flow released from Folsom Reservoir storage under Alternative 3 compared to the No Action Alternative would have both beneficial and adverse predicted effects on flows (Table O-259). Under Alternative 3 compared to the No Action Alternative, the largest decreases were in June and July with an average across all water year types of 29% and 13% decreases respectively, resulting in a potentially negative effect. Beneficial increases in flow are predicted to occur in a dry year in March and April with an average across all water types of an increase of 6% in March and 16% in April, a minor to moderate beneficial effect.

For the period of juvenile rearing and emigration (December through July), CalSim 3 modeling indicates that the average flow released at H street under Alternative 3 compared to the No Action Alternative would have both beneficial and negative predicted effects on flows (Table O-260). Under Alternative 3 compared to the No Action Alternative, the largest decreases were in June and July with an average across all water year types of 27% and 12% decreases respectively, resulting in a potentially negative effect. Beneficial increases in flow are predicted to occur in a dry year in March and April with an average across all water types of an increase of 6% in March and 16% in April.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 71 for Hazel Avenue and Table 72 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F upper incipient lethal temperature (UILT) for juveniles during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 73 for Hazel Avenue and Table 74 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 75 for Hazel Avenue and Table 76 for Watt Avenue.

Results for the three analyses are summarized in Table O-87. Table O-87 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability, there were zero and one water-month combinations (0% and 4.0%, respectively) with favorable results at both Hazel and Watt Avenue (Table O-87). There were zero and three combinations (0% and 12.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 75.2°F upper incipient lethal temperature (UILT) for juveniles, there were zero combinations (0%) with favorable results at both Hazel and Watt avenues. There were also zero (0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration, there were one and two month-water type combinations (4.0% and 8.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water type combinations (8.0% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that Alternative 3 would have positive (4% - 8% favorable) and negative (8% - 12% unfavorable) water temperature-related effects on fall-run Chinook salmon juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There may be both beneficial and adverse impacts of seasonal operations on fall-run Chinook salmon fry rearing and emigration in the lower American River based on analyses of simulated flows and water temperatures under Alternative 3 in comparison with the No Action Alternative. Under Alternative 3, changes in flows are expected to slightly increase in March and April on average among all water year types and would have decreases in June and July.. There would be negligible water temperature-related impacts of Alternative 3 on fall-run Chinook salmon juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue. There would be similar to minor changes to water temperatures for spawning initiation, pathogen virulence, and egg incubation and fry emergence.

Adult Upstream Migration

Adult fall-run Chinook salmon enter the lower American River from about mid-September through January, with peak migration from approximately mid-October through December (Williams 2001).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

For the period of adult migration (September through January), CalSim 3 modeling indicates that the average flow below Nimbus Dam under Alternative 3 compared to the No Action Alternative would have both beneficial and adverse predicted effects on flows (Table O-259). While the average of all water year types suggests overall negligible potential effects there are notable fluctuations in the critically dry years with a predicted decrease in flows of 29% in November, and an increase in flows of 62% in December, a significantly beneficial effect.

For the period of adult migration (September through January), CalSim 3 modeling indicates that the average flow released at H street under Alternative 3 compared to the No Action Alternative would have be very similar to that below Nimbus Dam with both beneficial and adverse predicted effects on flows (Table O-260). While the average of all water year types suggests overall negligible potential effects there are notable fluctuations in the critically dry years with a predicted decrease in flows of 31% in November, and an increase in flows of 62% in December, a significantly beneficial effect.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 59 for Hazel Avenue and Table 60 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 61 for Hazel Avenue and Table 62 for Watt Avenue.

Results for the two analyses are summarized in Table O-88. Table O-88, as described in Section O.4.12.3.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 37.9°F to 68°F successful migration range for adult fall-run Chinook salmon under, there were six and zero month-water combinations (17.1% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-88). There were one and seven month-water combinations (2.9% and 20.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for adult migration, there were zero and one month-water combinations (0.0% and 2.9%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were four and one month-water combinations (11.4% and 2.9%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results indicate that Alternative 3 would have positive (2.9% - 17.1% favorable) and negative (2.9% - 20% unfavorable) water temperature-related effects to fall-run Chinook salmon adult upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There may be both beneficial and adverse impacts of seasonal operations on fall-run Chinook salmon adult migration in the lower American River based on analyses of simulated flows and water temperatures under Alternative 3 in comparison with the No Action Alternative. The largest differences are in the critically dry years with a predicted decrease in flows below Nimbus Dam of 29% in November, a moderately negative impact and an increase in flows of 62% in December, a significantly beneficial impact, similar flows are predicted at H street. Temperature models suggest that similar negligible beneficial and adverse water temperature-related impacts to fall-run Chinook salmon adult upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue. There would be changes to water temperatures for favorable and unfavorable conditions for successful migration, and increases in unfavorable conditions for pathogen virulence.

O.6.14.4 San Joaquin River

Fall-run Chinook salmon adults migrate upstream through the San Joaquin River past Vernalis between September and November. Juvenile fall-run Chinook salmon migrate downstream past Vernalis primarily January through May. See Section O.1.8.1 for additional information.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Under Alternative 3, flows in the San Joaquin River at Vernalis, as shown by CalSim 3 model simulations, would decrease in October and April in all water year types, and in November in above normal, below normal, and dry water year types compared to the No Action Alternative. Flows decrease in October between 6% to 7%, with average flows at 1,925 cfs. Flows decrease in April between 11% and 20%, with average monthly flows at 1,862 cfs. Flows in January through March, and in May are generally similar to the flows under the No Action Alternative, though with a minor decrease in flows in above normal water years in January (7%), and in critically dry water years in March (10%). Table O-263 provides the monthly average flows in the San Joaquin River at Vernalis.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on fall-run Chinook salmon in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Changes in flows from seasonal operations under Alternative 3 compared to the No Action Alternative may have a minor to moderate impacts on migrating adult and juvenile fall-run Chinook salmon. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.6.14.5 Bay-Delta

Juvenile Rearing and Emigration

Most fall-run Chinook salmon fry rear in freshwater from December through June, with out-migration as smolts occurring primarily from January through June, with presence in the Delta in December through July. In general, fall-run Chinook salmon fry abundance in the Delta increases following high winter flows. Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. Late fall-run Chinook salmon migrate may be found in the Delta between December and April. See Section O.1.9.1 for additional information.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Zone of Influence

Differences in hydrology under Alternative 3 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. With incremental decreases in OMR under Alternative 3 and the No Action Alternative, proportional overlap at these three locations decreases. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under Alternative 3 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 3, Sacramento River Winter-run Chinook Salmon ESU (Section O.6.8.2, *Zone of Influence*).

Flow into Junctions

For a full description of Flow into Junctions model background, see Section O.4.8.2, *Sacramento River Winter-run Chinook Salmon ESU, Juvenile Rearing and Emigration in the Bay-Delta*. The following section covers discussion of the Central Valley Project and Head of Old River junctions. An expanded set of junction analysis results can be found in Attachment I.10, *Flow into Junctions*.

Under Alternative 3 in the -2,000 and -3,500 OMR bins, predicted proportion of flow entering the Central Valley Project (CVP) is greater than the No Action Alternative, and less than the No Action Alternative in the -5,000 and <-5,500 OMR bins. Changes in predicted proportion of flow entering the CVP when OMR was -2,000, -3,500, and -5,000 were less than ± 0.0406, indicating

a negligible difference from the No Action Alternative. However, when OMR was <-5,500 the change in flow into CVP was -0.0933, indicating that slightly less flow will be routed into CVP under Alternative 3 than when compared to the No Action Alternative.

Under Alternative 3 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the Head of Old River (HOR) is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.0404, indicating a negligible difference between Alternative 3 and the No Action Alternative.

Summary

Alternative 3 relative to the No Action Alternative is expected to influence flow into the Head of Old River and CVP junctions, due to differences in flow. Under Alternative 3, no change to possibly less flow into CVP under OMR -3,500; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 3 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Fall-run / Late Fall-run Chinook Salmon ESU

Fall-run Chinook Salmon: Salvage Density

Predictions from the salvage density model for Fall-run Chinook salmon include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through July Alternative 3 was greater than predicted average monthly loss under the No Action Alternative for dry and critically dry water year types, predicted loss was lower for wet, above normal, and below normal water year types. Predicted average monthly loss at Banks under Alternative 3 had a range from 11% higher for critically dry water year types to 41% lower for wet water year types (Table O-89). Predicted average monthly loss of fall-run Chinook salmon at CVP Jones Pumping Plant for the months of November through August Alternative 3 was less than predicted average monthly loss under the No Action Alternative for all water year types. The range of predicted loss for fall-run Chinook salmon at Jones under Alternative 3 compared to the No Action Alternative was from 81% lower in dry water year types to 59% lower for wet water year types (Table O-90). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Late Fall-run Chinook Salmon: Salvage Density

Predictions from the salvage density model for late fall-run Chinook salmon include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of late fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through April and all water year types Alternative 3 was lower than

predicted average monthly loss under the No Action Alternative. Predicted average monthly loss at Banks under Alternative 3 had a range from 15% lower for below normal water year types to 49% lower for dry water year types (Table O-91). Predicted average monthly loss of late fall-run Chinook salmon at CVP Jones Pumping Plant for the months of October through April and all water year types Alternative 3 was less than predicted average monthly loss under the No Action Alternative. The range of predicted loss for late fall-run Chinook salmon at Jones under Alternative 3 compared to the No Action Alternative was from 25% lower in wet water year types to 58% lower for dry water year types (Table O-92). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Summary

The predicted monthly entrainment of fall-run Chinook salmon at Banks Pumping Plant is expected to be substantially increased under Alternative 3 compared to the No Action Alternative in wet and above normal water years causing substantial impacts to fall-run Chinook salmon, however entrainment would be similar to the No Action Alternative in below normal, dry water years and moderate in critically dry water years. The predicted monthly entrainment of fall-run Chinook salmon at the Jones Pumping Plant would be increased compared to the No Action Alternative in all water year types. Late fall-run Chinook salmon entrainment at both Banks and Jones Pumping Plants would be increased under Alternative 3 compared with the No Action Alternative.

Potential Changes to Through Delta Survival of Fall-run / Late Fall-run Chinook Salmon ESU

Fall-run Chinook Salmon: Delta Passage Model

Under Alternative 3, in all water year types, predicted mean survival of fall-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to 0.022. There is not a substantial difference in predicted proportion of fall-run Chinook salmon surviving to Chipps Island between Alternative 3 and the No Action Alternative.

Late Fall-run Chinook Salmon: Delta Passage Model

Under Alternative 3, in all water year types, predicted mean survival of late-fall-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted survival to Chipps Island in all water year types less than or equal to 0.008. There is not a substantial difference in predicted proportion of late-fall-run Chinook salmon surviving to Chipps Island between Alternative 3 and the No Action Alternative.

Summary

Under Alternative 3, there would be negligible changes in through Delta survival of both fall-run and late fall-run Chinook salmon through the Delta to Chipps Island compared to the No Action Alternative.

O.6.14.6 Stanislaus River

Spawning and Egg Incubation

Peak spawning for fall-run Chinook salmon in the Stanislaus River typically occurs in November with roughly 7% of spawning occurring prior to November 1, and 2% prior to October 15. The few redds created during late September and early October are typically in the reach just below Goodwin Dam with spawning typically ending in December.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Spawning Habitat—Flow Analyses

The results for Alternative 3 show a consistent trend of reduction in mean spawning WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the shape of the fall-run spawning WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show reduced WUA with increased flow, except at the lowest and highest flows (less than about 200 cfs to 500 cfs and greater than about 1,000 cfs, respectively). CalSim 3 mean monthly flows below Goodwin Dam, which is immediately upstream of the WUA study reach, are 200 cfs or above in all water year types, with flow generally increasing from critically dry to wet water years during months of the October through December fall-run spawning period, except December (Table O-261). The mean spawning WUA estimates for Alternative 3 are similar to or moderately higher than those under the No Action Alternative, ranging from 0.2% higher in dry water to 5.9% higher in above normal water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fall-run Chinook salmon spawning period, median spawning WUA under Alternative 3 is higher than the median under the No Action Alternative in November and December and is about the same in October (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that mean spawning WUA for fall-run Chinook salmon are about the same for Alternative 3 and the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 55 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult spawning pathogen virulence threshold during October through January are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 56 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 57 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 58 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-93. Table O-93 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 42.1°F to 55°F range for spawning initiation there were zero month-water year type combinations (0.0%) with favorable results and one month-water year type combinations (5.0%) with unfavorable results at Orange Blossom Bridge (Table O-93). For the 59.9°F adult spawning pathogen virulence threshold there were no month-water year type combinations (0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence there was one month-water year type combinations (5.0%) with favorable and zero combinations (0.0%) with unfavorable results at Orange Blossom Bridge. For the 59.9°F fry pathogen virulence threshold there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge. These results suggest that Alternative 3 would have negligible water temperature-related effects on fall-run Chinook salmon spawning and egg incubation.

Summary

There may be both adverse and beneficial impacts of seasonal operations in the Stanislaus River on fall-run Chinook salmon spawning and egg incubation based on analyses of simulated flows under Alternative 3 in comparison with the No Action Alternative. Spawning habitat area would be generally similar under Alternative 3 compared to the No Action Alternative. Modeled water temperature results were variable but suggests only negligible beneficial and adverse water temperature-related impacts on fall-run Chinook salmon spawning and egg incubation. There would be similar conditions affecting spawning initiation, egg incubation and fry emergence, and pathogen virulence.

Juvenile Rearing and Emigration

Fall-run juvenile rearing in the Stanislaus River typically occurs from January through May (Stanislaus River Fish Group 2004). Fry migration generally occurs from January through March, followed by smolt migration from April through May (Bureau of Reclamation 2012).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Rearing Habitat—WUA Flow Analyses

The results for fall-run fry rearing WUA under Alternative 3 show little variation among water year types in mean rearing fry WUA, except for lower means in above normal and wet water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the fall-run fry WUA curves, which show reduced WUA with increased flow, especially in the Orange Blossom Bridge and Riverbank reaches (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which are the longest segments of the study. Mean fry rearing WUAs under Alternative 3 is lower than under the No Action Alternative in all water year types, but the reductions are small, ranging from 0.9% lower for critically dry water years to 2.4% lower for above normal water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fry rearing period, fry rearing WUA is similar under Alternative 3

and the No Action Alternative in February, March and May, and is higher under Alternative 3 in April (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results for juvenile rearing WUA under Alternative 3 show no consistent change with water year type (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in juvenile rearing WUA between Alternative 3 and the No Action Alternative are small, ranging from a 1.0% reduction for above normal water years to a 3.4% increase for dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the juvenile rearing period, differences in the median WUAs between Alternative 3 and the No Action Alternative are small, except for a much higher medias under Alternative 3 in March and October (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that fry and juvenile rearing WUA for fall-run Chinook salmon under Alternative 3 is similar to that under the No Action Alternative.

Rearing Habitat—ASH Flow Analyses

The results of the Area of Suitable Habitat (ASH) analysis for fall-run fry and juvenile rearing are quite different from the rearing WUA results described above. The mean ASH estimates vary more strongly with water year type than the rearing WUA estimates for both fry and juvenile fall-run, consistently increasing from critically dry to wet years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the overall relationship between flow and ASH for both life stages as determined from modeling and field studies (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in fry and juvenile ASH between Alternative 3 and the No Action Alternative are highly variable, including large increase in mean ASH under Alternative 3 for both wet and dry water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The increases for fry are 10.2% for wet years and 17.5% for dry years, while those for juveniles are 10.5% and 33.0% for wet and dry water years, respectively. The other differences for fry range from a reduction of 1.4% for above normal water years to an increase of 8.4% for below normal water years, while the other differences for juveniles range from 0.7% higher for above normal water years to 7.2% higher for below normal water years. For the individual months of the fall-run fry rearing period, median ASH under Alternative 3 relative to the No Action Alternative is higher in February and March and similar in April and May.

Overall, the results indicate that fry and juvenile rearing ASH for fall-run Chinook salmon are higher or similar under Alternative 3 relative to the No Action Alternative, depending on water year type.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 59 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F upper incipient lethal temperature (UILT) for juveniles during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 60 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F

pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 61 for Orange Blossom Bridge.

Results for the three analyses are summarized in Table O-94. Table O-94, as described in Section O.4.14.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 3 for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability there were zero month-water year type combinations (0.0%) with favorable results and three month-water year type combinations (15.0%) with unfavorable results at Orange Blossom Bridge (Table O-94). For the 75.2°F upper incipient lethal temperature (UILT) for juvenile fall-run Chinook salmon there were no month-water year type combinations (0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration there was one month-water year type combination (5.0%) with favorable results and zero combination (0.0%) with unfavorable results at Orange Blossom Bridge.

These results suggest that there would be negative water temperature-related effects of Alternative 3 on fall-run Chinook salmon juvenile rearing and emigration.

Summary

There are expected adverse and beneficial impacts of seasonal operations on fall-run chinook salmon juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 3, in comparison to the No Action Alternative. Under Alternative 3, changes in flows are expected to have similar increases and decreases in rearing habitat in the WUA analysis and minor to moderate increases in rearing habitat area in the ASH analysis. Modeled water temperature results were variable but suggest only negligible beneficial and adverse water temperature-related impacts on fall-run Chinook salmon rearing. There would be changes in unfavorable conditions for growth, smoltification, predation vulnerability and pathogen virulence.

Adult Upstream Migration and Holding

Fall-run Chinook salmon adults generally migrate upstream from late September through December with peak migration from late October through early November in the Stanislaus River.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

For the period of adult upstream migration and holding of fall-run Chinook salmon (September through December), CalSim 3 modeling under Alternative 3 compared to No Action Alternative indicates that there may be negative effects as a result of decreases in flows in all water year types. Overall flows are similar with the exception of December with an average 19% decrease in flows among all water year types. This effect in December does not occur during a critically dry year with no difference predicted during this time.

For the period of adult upstream migration and holding of fall-run Chinook salmon (September-December), CalSim 3 modeling under Alternative 3 compared to No Action Alternative indicates that average flow released at the mouth of the Stanislaus River would be similar to that modeled at Goodwin Dam where overall flows are similar to the No Action Alternative with the exception of December with an average 15% decrease in flows among all water year types (Tables O-261 and O-262).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during July through December are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 51 for Orange Blossom Bridge and Table 52 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration during July through December are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 53 for Orange Blossom Bridge and 54 for above the confluence with the San Joaquin River.

Results for the two analyses are summarized in Table O-95. Table O-95, as described in Section O.4.14.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 3 for the 37.9°F to 68°F successful migration range there were no month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-95). There were zero and two month-water year type combinations (0.0% and 6.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence of the San Joaquin River. For the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration there were no month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. There were three and two month-water year type combinations (10.0% and 6.7%, respectively) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River, respectively.

These results suggest that Alternative 3 would have negative water temperature-related effects on fall-run Chinook salmon upstream holding and migration in the Stanislaus River at Orange Blossom Bridge and above the confluence of the San Joaquin River.

Summary

For the period of adult upstream migration and holding of fall-run Chinook salmon (September-December), CalSim 3 modeling under Alternative 3 compared to the No Action Alternative predicts that there may be adverse impacts as a result of a decrease in flows in December with a 19% average decrease among all water year types at Goodwin Dam and 15% reduction at the mouth. Water temperature model results also suggest that Alternative 3 would have adverse water temperature-related impacts on fall-run Chinook salmon upstream migration and holding. There would be changes in unfavorable conditions for successful migration and pathogen virulence.

O.6.15 White Sturgeon

O.6.15.1 Sacramento River

Spawning and Egg Incubation

Spawning occurs in deep water in the middle and lower Sacramento River from near Verona (~RM 80) to just upstream of Colusa (~RM 156) from late February to early June, peaking during March and April, (Section O.1.3.2.6, *White Sturgeon*). Because the incubation time for white sturgeon is so short, the peak impacts analysis period for incubating eggs is also considered to be March and April.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the March and April spawning and egg incubation period for white sturgeon, CalSim 3 estimates of mean monthly flows at Wilkins Slough under Alternative 3 range from about 4,400 cfs for April of critically dry water years to about 18,100 cfs for March of wet water years (Table O-250). Because white sturgeon spawn in deep pools, these flow levels are likely to be adequate for spawning and egg incubation, so no adverse effects are expected to result. Alternative 3 relative to the No Action Alternative has differences in flow that are small in both months (up to 2%), but flows are higher (11%) for Alternative 3 in April of critically dry water years and lower (up to 7%) in April of below normal and dry water years (Table O-250).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 61°F upper limit for optimal egg incubation during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 291 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 68°F upper limit for embryo hatching during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 292 for Hamilton City.

Results for the two analyses are summarized in Table O-96. Table O-96, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 61°F upper limit for optimal egg incubation, there was one month-water year type combination (5.0% of total combinations during the period) with favorable results and three combinations (15.0%) with unfavorable results at Hamilton City (Table O-96). For the 68°F upper limit for embryo hatching, there were no combinations (0%) with favorable or unfavorable results at Hamilton City. These results suggest that there would be negative water temperature-related effects of Alternative 3 on white sturgeon spawning and egg incubation in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minimal beneficial impacts on spawning habitats due to differences in flow. Differences in water temperature between the two alternatives are expected to have possible adverse impacts on spawning in the Sacramento River.

Larval and Juvenile Rearing and Emigration

The white sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch (Heublein et al. 2017a, Deng et.al 2002). Therefore, since white sturgeon spawn from late February to early June, peaking in March and April, the larval period is considered to be March through June. Juvenile white sturgeon are believed to initiate a secondary dispersal (the primary dispersal occurring at the larval stage) in spring by actively swimming downstream during the night (Heublein et al. 2017a). The juvenile emigration period is considered to be April through July. Therefore, the effects analysis period for larvae and juvenile rearing and emigration is considered to be March through July.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the white sturgeon larval and juvenile rearing and emigration period, approximately April to July, CalSim 3 estimates of mean monthly flows at Wilkins Slough under Alternative 3 range from about 3,200 cfs for May of critically dry water years to about 14,600 cfs for April of wet water years (Table O-250). CalSim 3 results indicate that flows during April through July would generally decrease (up to 28%) with Alternative 3 compared to the No Action Alternative. However, under Alternative 3 compared to the No Action Alternative, flows would increase in May of wet and above normal years (up to 37%) and increase (up to 15%) in April, June, and July of critically dry years (Table O-250). These flow levels are likely to be adequate for white sturgeon rearing and emigration; therefore, Alternative 3 would likely have a potential adverse effect on larval and juvenile white sturgeon relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66°F limit above which stress is observed in juvenile white sturgeon year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 293 for Hamilton City.

Results for the analysis are summarized in Table O-97. Table O-97, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 66°F stress limit for juvenile white sturgeon, there were four month-water year type combinations (6.7% of total combinations during the period, respectively) with favorable results and two combinations (3.3%) with unfavorable results at Hamilton City (Table O-97). These results suggest that there would be negligible water temperature-related effects of Alternative 3 on white sturgeon larval and juvenile rearing and emigration in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have negligible impacts or possible adverse impacts on rearing and emigration due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on rearing and emigration in the Sacramento River due to differences in water temperature.

Adult Upstream Migration and Holding

Adults ready for spawning likely move into the lower reaches of the Sacramento River during early winter to begin their upstream migration (Section O.1.3.2.6, *White Sturgeon*). Upstream migration appears to be rapid, with minimal holding time (Schaffter 1997, Heublein et al. 2017a). Based on rapid upstream migration, short egg incubation period, and larval presence in the Sacramento River; the adult upstream migration and holding period is considered to be December to February for this effects analysis.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the white sturgeon adult upstream migration and holding period, approximately December to February, CalSim 3 estimates of mean monthly flows at Wilkins Slough under Alternative 3 range from about 6,700 cfs for January of critically dry water years to about 20,000 cfs for February of wet water years (Table O-250). CalSim 3 results indicate that flows during December through February would generally remain similar (up to 5%) with Alternative 3 compared to the No Action Alternative, with the exception of increased flows in December of above normal water years (7%) and January of critically dry water years (Table O-250). Alternative 3 would have a similar effect on upmigrating and holding adult white sturgeon relative to the No Action Alternative.

Water Temperature Analysis

Potential water temperature-related effects to adult white sturgeon upstream migration and holding in the Sacramento River were evaluated by assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperature for adult white sturgeon (Israel et al. 2009) at Hamilton City (Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 2).

Full results of the analysis assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperature for adult white sturgeon during November through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 294 for Hamilton City.

Results for the analysis are summarized in Table O-98. Table O-98, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 77°F upper limit of suitable water temperature for adult white sturgeon, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results (Table O-98). These results suggest that there would be negligible water temperature-related effects of Alternative 3 on adult white sturgeon upstream migration and holding in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on migration and holding habitat due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on migration and holding in the Sacramento River due to differences in water temperature.

O.6.15.2 Lower American River

Limited quantitative information is available on the distribution and status of white sturgeon in the lower American River; however, small numbers of adults apparently use the lower American River, as evidenced by sturgeon report cards submitted to the CDFW by anglers in recent years (Section O.1.6.2.1, *Fish Evaluated in the Lower American River*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Adult white sturgeon have been reported by anglers in the lower American River during all months of the year, peaking in March-April and November-December (California Department of Fish and Wildlife 2023i). During all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 3 range from about 719 cfs for October of critically dry water years to about 12,311 cfs for February of wet water years (Table O-259). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 3 compared to the No Action Alternative, with a few exceptions. Flows under Alternative 3 for all water years would decrease in June and July (up to 27%) and increase in March, April, and August (up to 16%) (Table O-259).

During all months, CalSim 3 estimates of mean monthly flows at H Street under Alternative 3 range from about 603 cfs for October of critically dry water years to about 12,332 cfs for February of wet water years (Table O-260). For all water year types, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 5%) under Alternative 3 compared to the No Action Alternative, with a few exceptions. Flows under Alternative 3 for all water years would decrease in June and July (up to 29%) and increase in March, April, and August (up to 16%) compared to the No Action Alternative (Table O-260).

White sturgeon are not likely to be affected by changes in flow under Alternative 3 compared to the No Action Alternative due to their limited distribution in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperatures for adult white sturgeon year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 77 for Hazel Avenue and Table 78 for Watt Avenue.

Results for the analysis are summarized in Table O-99. Table O-99, as described in Section O.4.15.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 77°F upper limit of suitable water temperatures for adult white sturgeon, there were zero month-water combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-99). There were also zero month-water combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue.

These results suggest that Alternative 3 would have negligible water temperature-related effects to non-spawning white sturgeon in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on white sturgeon habitat due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible water temperature-related impacts on white sturgeon habitat in the lower American River due to their limited distribution in this geography.

O.6.15.3 San Joaquin River

Little is known about white sturgeon populations inhabiting the San Joaquin River. White sturgeon spawning in the San Joaquin River was documented for the first time in 2011 and confirmed in 2012. Although the majority of sturgeon likely spawn in the Sacramento River, the results of these surveys confirm that white sturgeon do spawn in the San Joaquin River in both wet- and dry-year conditions and may be an important source of production for the white sturgeon population in the Sacramento–San Joaquin River system (Section O.1.8.2.4, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Using the Sacramento River as a surrogate, it can be inferred that the spawning period for white sturgeon in the San Joaquin River also occurs in deep water from late February to early June, peaking during March and April, (Section O.1.8.2.4, *White Sturgeon*). Because the incubation time for white sturgeon is so short, the peak impacts analysis period for incubating eggs is also considered to be March and April. Since confirmed spawning events took place in the San Joaquin River, it is reasonable to assume that rearing larvae, emigrating juveniles, and migrating adults are also present in the San Joaquin River, but due to the lack of information on these life stages they are not part of this analysis.

During the evaluated months in the spawning period, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 3 range from about 1,832 cfs for March of critically dry water years to about 12,558 cfs for March of wet water years (Table O-263). CalSim 3 results indicate that there would be minimal differences in flows during March (up to 4%) except in critically dry years when flows would moderately decrease (10%) under Alternative 3. Flows would also moderately decrease in April of all water year types (up to 20%) under Alternative 3 compared to the No Action Alternative (Table O-263). Due to spawning occurring in deep pools, it is not anticipated that flows under Alternative 3 would have an effect on white sturgeon spawning compared to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on white sturgeon in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 3 relative to the No Action Alternative is expected to have negligible impacts to possible adverse impacts on spawning white sturgeon due to differences in flow. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.6.15.4 Bay-Delta

Juvenile Rearing and Emigration

White sturgeon are believed to be most abundant within the Bay-Delta region. Juveniles can be found throughout the Delta year-round. Additionally, white sturgeon larvae have been observed to be flushed farther downstream in the Delta and Suisun Bay in high outflow years, but otherwise rear higher in the system (Section O.1.9.1.6, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

<u>CalSim 3 Flows</u>

During all months, CalSim 3 estimates of mean monthly flows in the Sacramento River at Rio Vista under Alternative 3 range from about 3,626 cfs for September of critically dry water years to about 105,899 cfs for February of wet water years (Table O-256). For all water year types, CalSim 3 results indicate that differences in flows would generally increase in winter and spring months and decrease in summer and fall months under Alternative 3 compared to the No Action Alternative. Flows under Alternative 3 for wet water years would substantially decrease in June through September (up to 39%) and moderately increase in May and December (up to 23%). Flows in above normal water years would decrease in September and October (up to 19%), substantially decrease in June, July, and August (up to 53%) and increase in January, April, and December (up to 15%), and substantially increase in May (30%). Flows in below normal water years would substantially decrease in June and July (up to 49%), moderately decrease in August (23%), and moderately increase in February, March, April, and December (up to 20%). Flows in dry water years would moderately decrease in June and July (up to 26%) and moderately increase in March, April, August, and December (up to 26%). Flows in critically dry water years would moderately decrease in September (6%) and moderately increase in March, April, June,

July, August, and December (up to 28%) (Table O-256). It is not anticipated that flows under Alternative 3 would have an effect on white sturgeon juveniles compared to the No Action Alternative and may have a positive effect on juveniles during critically dry years.

CalSim 3 estimates of mean monthly total exports of SWP and CVP under Alternative 3 range from 966 cfs for August of critically dry water years to about 7,612 cfs for January of wet water years (Table O-253). For all water year types, CalSim 3 results indicate that differences in exports during January through December would substantially decrease (up to 79%) under Alternative 3 compared to the No Action Alternative with a couple exceptions. Exports would moderately increase in October of dry water years (11%), and August of critically dry water years (24%) (Table O-253). Changes in exports under Alternative 3 may have a positive effect on white sturgeon juveniles compared to the No Action Alternative due to increased Delta outflow.

Delta Outflow vs Sturgeon YCI

Differences in year class strength between Alternative 3 and the No Action Alternative are expected to be minorly beneficial. For additional effects of spring Delta outflow vs white sturgeon YCI under Alternative 3, refer to the analysis in Section O.6.11.3.1, *[Green Sturgeon] Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 3 relative to the No Action Alternative are expected to have potential beneficial impacts on white sturgeon year class strength due to differences in flow.

Potential Changes to Entrainment of White Sturgeon

Salvage Density

Differences in exports under Alternative 3 compared with the No Action Alternative may have effects on white sturgeon entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model.

Predictions from the salvage density model for white sturgeon include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of white sturgeon under Alternative 3 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant was lower in nearly all water year types, except dry water years at SWP Banks Pumping Plant when it would be similar; no loss is anticipated in critically dry year types at either facility (Tables O-100 and O-101). The SWP Banks Pumping Plant predicted average monthly loss was up to 47% lower for December through March and May through August (Table O-100). At the CVP Jones Pumping Plant predicted average monthly loss was up to 80% lower for May through November of above normal water year types (Table O-101). Historical loss of white sturgeon at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Summary

Differences in export between Alternative 3 and the No Action Alternative are expected to have negligible impacts on the entrainment of juvenile white sturgeon at both facilities. Modeled results from the quantitative model show possible beneficial impacts, but since white sturgeon are salvaged so rarely, the numbers may not be representative.

Subadult and Adult Residency

White sturgeon are believed to be most abundant within the Bay-Delta region. Non-spawning adults can be found throughout the Delta year-round. When not undergoing spawning or ocean migrations, adults and subadults are usually most abundant in brackish portions of the Bay-Delta (Section O.1.9.1.6, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Juveniles, subadults and non-spawning adults are in the Bay Delta year-round, refer to the CalSim 3 flow analysis in the juvenile life stage (Section O.6.15.5.1, *Juvenile Rearing and Emigration*) for changes in flow under Alternative 3 compared to the No Action Alternative.

Summary

Alternative 3 relative to the No Action Alternative is expected to have possible beneficial impacts on white sturgeon year class strength due to differences in flow.

O.6.16 Native Minnows

O.6.16.1 Sacramento River

Sacramento Splittail, Hardhead, and Sacramento Hitch

- **Sacramento Splittail:** Historically, Sacramento splittail was widespread in the Sacramento River from Redding to the Delta (Rutter 1908, as cited in Moyle et al. 2004). This distribution has become somewhat reduced in recent years (Sommer et al. 1997, 2007b). During drier years there is evidence that spawning occurs farther upstream (Feyrer et al. 2005). Adult splittail migrate upstream in the lower Sacramento River to above the mouth of the Feather River and into the Sutter and Yolo Bypasses (Sommer et al. 1997; Feyrer et al. 2005; Sommer et al. 2007b). Each year, mainly during the spring spawning season, a small number of individuals have been documented at the Red Bluff Pumping Plant and the entrance to the GCID intake (Moyle et al. 2004).

  Most juvenile Sacramento splittail move from upstream areas downstream into the Delta from April through August (Meng and Moyle 1995; Sommer et al. 2007b). The production and recruitment of YOY Sacramento splittail is largely influenced by extent and duration of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Sommer et al. 1997; Moyle et al. 2004; Feyrer et al. 2006).

- **Hardhead:** Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986). They migrate upstream and into tributary streams as far as 45 miles (72.4 km) to spawning sites. Spawning behavior has not been documented, but it is assumed to be similar to that of the pikeminnow, which deposit their eggs over gravel-bottomed riffles, runs, and at the head of pools (Moyle et al. 1995). Hardhead larvae and juveniles likely inhabit stream margins with abundant cover and move into deeper habitats as they grow larger. Adults occupy the deepest part of pools. Juvenile and adult hardhead are present in the Sacramento River year-round. Thompson et al. (2012) found that adults tend to prefer water temperatures near 67°F (19.4°C), but were frequently observed between 57.2-78.8°F (14°C-26°C), and individuals have been captured at RBDD, where water temperatures are generally much cooler (Tucker et al. 1998).
- **Sacramento Hitch:** Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta (Moyle et al. 2015). Sacramento hitch were not known to occur in high abundance in the Sacramento watershed, but they are known to prefer shallow backwater areas and historically were observed in the upper and lower Sacramento River and north Delta (Brown & May, 2006; Robinson & Safran, 2014).

  Moyle et al. (2015) summarized habitat and distribution: Spawning takes place mainly in riffles of streams tributary to lakes, river, and sloughs after flows increase in response to spring rains, but spawning requirements are in need of further documentation. Moyle et al. (2015) indicate that YOY hitch spend the next two months after hatching shoaling in shallow water or staying close to aquatic plants before moving out into more open water at around 50-mm fork length.

Potential Changes to Sacramento Splittail, Hardhead, and Sacramento Hitch from Seasonal Operations

<u>CalSim 3 Flows</u>

The greatest factor in determining native minnow spawning success and recruitment is the amount and duration that crucial floodplain spawning areas are inundated during the period of native minnow migration and spawning. In wet years flows over 22,500 cfs at Tisdale, the first flood control gate, would cause the Tisdale weir to begin spilling into the Sutter Bypass (DWR 2010b). Adult migration generally occurs during the late winter with juvenile outmigration into the Delta occurring in spring/early summer. Exact migration, spawning and outmigration timing are not well understood for native minnows, so flows were examined for the months of December through May.

CalSim 3 modeling indicates that average flow released at Keswick Dam under Alternative 3 would generally be similar to flows under No Action Alternative December through May, the range of average flows for the full simulation period are from 5,942 cfs (April) to 11,919 cfs (February) (Table O-248). Differences in average flows at Keswick Dam under Alternative 3 are from a 5% reduction (April) to a 8% increase (December) (Table O-248). Native minnows need adequate flows to allow access to upstream spawning/rearing habitat, with minimal differences in flows under Alternative 3 the effect on flow to native minnow is likely negligible as compared to the No Action Alternative.

For the full simulation period, the difference in average CalSim 3 flow estimates under Alternative 3 compared to the No Action Alternative at Wilkins Slough are minimal, with a range of 1% decrease in flows for April to a 16% increase in May (Table O-250). Under Alternative 3 CalSim 3 flow estimates at Wilkins Slough would have a negligible effect on native minnow spawning and migration as compared to the No Action Alternative. Slight increases in flows at Wilkins during the month of May could have a positive effect on native minnows allowing for more successful outmigration and higher levels of recruitment in the Delta.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 75°F observed range of suitable water temperatures for Sacramento splittail during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 307 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 84.2°F range of preferred temperatures in lab and field observations for Sacramento hitch non-spawning adults year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 308 for Keswick Dam, 309 for Red Bluff Diversion Dam, and 310 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 64°F optimal water temperature range for hardhead spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 311 for Keswick Dam and 312 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature outside the 57.2°F to 78.8°F commonly observed range of temperatures for non-spawning adult hardhead year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 314 for Keswick Dam and 315 for Red Bluff Diversion Dam.

Results for the four analyses are summarized in Table O-102. Table O-102, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 45°F to 75°F observed range for suitable Sacramento splittail spawning, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Hamilton City (Table O-102). For the 77°F to 84.2°F preferred range for non-spawning Sacramento hitch, there were no combinations (0%) with favorable or unfavorable results at any location analyzed. For the 59°F to 64°F optimal hardhead spawning range, there were zero and three combinations (0% and 20.0%, respectively) with favorable results at both locations analyzed. There were 0 and 5 combinations (0% and 33.3%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there were one and four combinations (1.7% and 6.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were three and three combinations (5.0% and 5.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 3 on native minnows in the Sacramento River.

Summary

Seasonal operations impacts on native minnows would likely be negligible or slightly beneficial based on the CalSim 3 and water temperature analysis with a few exceptions. Alternative 3 relative to the No Action Alternative is expected to have a minor beneficial impact due to differences in flow, with slight increases in the month of May for the lower river, possibly allowing for higher levels of outmigration. Adverse and beneficial water temperatures are shown in the temperature analysis for hardhead spawning under Alternative 3. Water temperature related impacts on Sacramento splittail and hitch are likely negligible below Keswick Dam and at RBDD.

O.6.16.2 Clear Creek

Hardhead

According to Moyle et al. 2015, hardhead mainly occupy canyon reaches and deep pools in Clear Creek. Hardhead are one of the non-target species regularly caught in the rotary screw traps in lower Clear Creek (Schraml and Chamberlain 2019a, 2019b, 2020, and 2021). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986). They migrate upstream and into tributary streams as far as 45 miles (72.4 km) to spawning sites.

Potential Changes to Hardhead from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning, the CalSim 3 modeling results show that throughout the full simulation period, average flows in Clear Creek are higher under Alternative 3 with the exception of a 6% reduction in February. Under Alternative 3 average flows in Clear Creek ranged from 230 cfs (April) to 312 cfs (February) (Table O-257). Even with a 6% reduction in February flows would remain generally high during the period of hardhead spawning and migration so the effect of seasonal operations under Alternative 3 compared to the No Action Alternative would likely be negligible.

Hardhead are present in Clear Creek all months of the year. During the full simulation period and for all months utilizing the CalSim 3 modeling results, average flows under Alternative 3 had a range from 99 cfs (August) to 312 cfs (February) (Table O-257). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from 33% lower (August) to 41% higher (May) (Table O-257). With the decrease in flows in February, flows would still remain relatively high during the winter and spring, but during the fall a substantial reduction in flows would likely have a negative effect on hardhead occupying Clear Creek by limiting suitable habitat, and prey availability.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 64°F optimal water temperature range for hardhead spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 57.2°F to 78.8°F commonly observed range of

temperatures for hardhead spawning year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 307 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-103. Table O-103, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 59°F to 64°F optimal hardhead spawning range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results (Table O-103). For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on native minnows in Clear Creek.

Summary

There are likely negligible impacts of seasonal operations on migrating and spawning adult Hardhead in Clear Creek based on temperature and simulated flow analysis for Alternative 3 as compared to the No Action Alternative. However, a reduction in flows during the fall would likely have a negative impact on juvenile and non-spawning adults occupying Clear Creek.

O.6.16.3 Lower American River

Hardhead and Sacramento Splittail

- **Hardhead:** The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are fairly common in the lower reaches of the lower American River. Hardhead are fairly common year-round in the lower reaches of the lower American River (Moyle 2002). Although migratory behavior of hardhead in the lower American River individuals is unknown, individuals from other large rivers, such as the Sacramento River, migrate into tributary streams during April and May. Hardhead typically spawn between April and May (Moyle 2002). Although hardhead early life history is largely unknown, young individuals likely remain along stream edges with dense cover and move into deeper water as they grow, which allows migrants to move back downstream in the current (Moyle 2002).

- **Sacramento Splittail:** Splittail likely spawn in the lower reaches of the lower American River (Sommer et al. 2008; Moyle et al. 2004). Because upstream migration is more directed and fish tend to swim farther upstream during wet years (Moyle 2002), more individuals are expected to use the lower American River in wet years. Although juvenile splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks of rearing on floodplain habitat (Bureau of Reclamation 2008). Most juveniles move downstream into the Delta from April to August (Meng and Moyle 1995). The primary factor potentially limiting the lower American River population of Sacramento splittail is availability of inundated floodplains for spawning and rearing habitats (Moyle et al. 2004).

Potential Changes to Hardhead and Sacramento Splittail from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning for flows in the lower American River below Nimbus the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 3 average flows in the lower American River below Nimbus ranged from 3,541 cfs (May) to 6,398 cfs (February) (Table O-259). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 1% reduction (May) to a 16% increase (April) (Table O-259). With minimal differences in flows native minnow migration and spawning would likely have a negligible affect under Alternative 3 compared to the No Action Alternative.

During the full simulation period, and all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 3 are from 1,461 cfs (October) to 6,398 cfs (February) (Table O-259). The difference in average flows under Alternative 3 as compared to the No Action Alternative for the full simulation period range from a 27% reduction (June) to a 16% increase (April) (Table O-259). With a slight increase in flows during March/April native minnows would likely benefit albeit slightly in the lower American River. However, a substantial reduction in flows in June may have a negative effect on native minnows. Given these two mechanisms, the effect on native minnows in the lower American River under Alternative 3 would likely be negligible as compared to the No Action Alternative.

During the December through May period for adult migration and spawning for flows in the lower American River at H street the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are minimal, with all but the month of May having an increase in flows. Under Alternative 3 average flows in the lower American River at H street ranged from 3,411 cfs (May) to 6,386 cfs (February) (Table O-260). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 1% reduction (May) to a 16% increase (April) for the full simulation period (Table O-260). With minimal differences in flows native minnow migration and spawning would likely have a negligible affect under Alternative 3 compared to the No Action Alternative. With a slight increase during the spawning period (March/April) native minnows spawning success may have a slight positive effect under Alternative 3.

During all months, and for the full simulation period, CalSim 3 estimates of mean monthly flows at H Street under Alternative 3 range from 1,353 (October) to 6,386 cfs (February) (Table O-260). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 29% reduction (June) to a 16% increase (April) for the full simulation period (Table O-260). With a slight increase in flows during March/April native minnows would likely benefit albeit slightly in the lower American River. However, a substantial reduction in flows in June/July may have a negative effect on native minnows. Given these two mechanisms, the effect on native minnows in the lower American River under Alternative 3 would likely be negligible as compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 75°F water temperature range observed for Sacramento splittail suitable spawning during February through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 87 for Hazel Avenue and Table 88 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the outside the 59°F to 64°F water temperature optimal range for hardhead spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 89 for Hazel Avenue and Table 90 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the outside the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 91 for Hazel Avenue and Table 92 for Watt Avenue.

Results for these three analyses are summarized in Table O-104. Table O-104, as described in Section O.4.16.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 45°F to 75°F temperature range observed for suitable spawning for Sacramento splittail under Alternative 3, there were zero month-water combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-104). There were also zero month-water combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue. For the 59°F to 64°F water temperature optimal range for hardhead spawning under Alternative 3, there were four and zero month-water combinations (26.7% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and five month-water combinations (6.7% and 33.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were three and two month-water combinations (5.0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were one and five month-water combinations (1.7% and 8.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

Overall, these results suggest that there would be positive and negative water temperature-related effects on native minnows in the lower American River.

Summary

There are likely negligible impacts of seasonal operations on native minnow in the lower American River based on the difference in simulated flows and the temperature analysis for Alternative 3 compared to the No Action Alternative. The temperature analysis for the lower American River at Hazel and Watt Avenue results suggest both beneficial and adverse impacts of water temperature on hardhead spawning, depending on the location. Water temperature related impacts on Sacramento splittail are likely negligible in the lower American River at Watt Ave and Hazel Ave. Similarly, the flow analysis in the lower American River shows an increase in flows during the spawning period for native minnows with a decrease during the period of outmigration. Native minnow spawning adults would likely benefit from Alternative 3, but outmigration success would likely be negatively impacted. Overall, given the flow and

temperature analysis the impact of Alternative 3 would likely be negligible for native minnows as compared to the No Action Alternative.

O.6.16.4 Stanislaus River

Hardhead

The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are a frequent catch in the lower Stanislaus River (Bradbury and Hickey 2019). The Stanislaus River compared to other systems in the San Joaquin watershed has higher discharge and albeit slightly cooler water for most of the year. Due to the more stream-like conditions the Stanislaus River is occupied by many native fish, including hardhead. The increased discharge has also limited many non-native fishes, concentrating them in the lower reaches. Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).

Potential Changes to Hardhead from Seasonal Operations

<u>CalSim 3 Flows</u>

During the December through May period for adult migration and spawning for flows in the Stanislaus River at the confluence with the San Joaquin the CalSim 3 modeling results show that throughout the full simulation period average flows generally increase, with a slight decrease during the months of December and January. Under Alternative 3 average flows in the Stanislaus River at the confluence ranged from 434 cfs (December) to 1,515 cfs (May) (Table O-262). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 15% reduction (December) to a 30% increase (March/April) for the full simulation period and months of December through May (Table O-262). Reduction in flows during the beginning of hardhead spawning migration period (December/January) are relatively small, but could limit migrating minnows to a degree. Increased flows during the remainder of the spawning and migration period (February-May) would likely have a positive effect on hardhead spawning and migration. Overall, hardhead spawning and migration would likely have a positive effect under Alternative 3 as compared to the No Action Alternative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the Stanislaus River at the confluence of the San Joaquin under Alternative 3 range from 330 cfs (August) to 1,267 cfs (February) (Table O-262). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 15% reduction (December) to a 38% increase (June) for the full simulation period and all months (Table O-262). Hardhead are present in the Stanislaus River all months of the year. With increased flows in the winter/spring spawning success and rearing would likely have a positive effect. However, decreased flows in the fall and early winter may have a negative effect on rearing and migration, but the difference in flows is minor and the effect would likely be minor as well. Overall, the effect of flow on hardhead in the Stanislaus River would likely be negligible or slightly positive for Alternative 3 as compared to the No Action Alternative.

During the December through May period for adult migration and spawning for average flows in the Stanislaus River below Goodwin Dam the CalSim 3 modeling results show that throughout the full simulation period flows will have a substantial increase in late winter/spring but will

have a slight decrease in the fall and early winter under Alternative 3 compared to the No Action Alternative. Under Alternative 3 average flows in the Stanislaus River below Goodwin Dam ranged from 398 cfs (December) to 1,309 cfs (May) (Table O-261). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 19% reduction (December) to a 23% increase (March) (Table O-261). Increased flows for the majority of the hardhead spawning and migration period would likely have a positive effect, but reduced flows in the early part of the migration period may limit migration slightly. Overall, Alternative 3 would likely have a positive effect on hardhead spawning and migration as compared to the No Action Alternative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the Stanislaus River below Goodwin Dam under Alternative 3 had a range from 271 cfs (July) to 1,309 cfs (May) (Table O-261). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 19% reduction (August) to a 37% increase (June) for the full simulation period, and all months (Table O-261). Hardhead are present in the Stanislaus River for all months of the year. The reduced flows during the beginning of the migration period may limit migration in some water year types, while increased flows in the late winter/spring would likely have a positive effect. Reduced flows in the fall would mostly be for wet water year types, given this, the overall effect would likely be positive for hardhead in the Stanislaus River under Alternative 3 as compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the outside the 59°F to 64°F water temperature optimal range for hardhead spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 868 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the outside the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 69 for Orange Blossom Bridge.

Results for these two analyses are summarized in Table O-105. Table O-105, as described in Section O.4.16.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 59°F to 64°F water temperature optimal range for hardhead spawning under Alternative 3, there was one month-water year type combination (6.7%) with favorable and unfavorable results at Orange Blossom Bridge (Table O-105). For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were three month-water year type combinations (5.0%) with favorable results and one month-water year type combinations (1.7%) with unfavorable results at Orange Blossom Bridge.

These results suggest that Alternative 3 would have negligible water temperature-related effects on native minnows in the Stanislaus River at Orange Blossom Bridge.

Summary

Utilizing the CalSim 3 flow analysis, Alternative 3 would have generally higher flows during important periods of the year for hardhead as compared to the No Action Alternative. Higher flows during the native minnow period of spawning, rearing, and outmigration would likely have a strong beneficial impact on native minnow populations in the Stanislaus River. However, based off the temperature analysis for the Stanislaus River the impact of temperature under Alternative 3 would be negligible. Given that the impact of water temperature under Alternative 3 are negligible but flow related impacts are beneficial, overall hardhead would likely have a beneficial impact as compared to the No Action Alternative.

O.6.16.5 San Joaquin River

Sacramento Splittail, Hardhead, and Sacramento Hitch

- **Sacramento Splittail:** Historically, Sacramento splittail were widespread in the San Joaquin River and found upstream to Tulare and Buena Vista lakes, where they were harvested by native peoples (Moyle et al. 2004). Today, Sacramento splittail likely ascend the San Joaquin River to Salt Slough during wet years (Baxter 1999). During dry years, Sacramento splittail are uncommon in the San Joaquin River downstream of the Tuolumne River (Moyle et al. 2004). The population of Sacramento splittail is largely influenced by extent and period of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Moyle et al. 2004).

- **Hardhead:** In the San Joaquin drainage, hardhead are present throughout tributary streams but are largely absent from the valley reaches of the San Joaquin River (Moyle et al. 2015, Moyle and Nichols 1973, Saiki 1984). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).

- **Sacramento Hitch:** Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta, but are now absent from the San Joaquin River and tributaries between Friant Dam and the Merced River (Moyle et al. 2015). Sacramento hitch are occasionally captured in low numbers in the lower San Joaquin River in the Mossdale trawl monitoring program (Interagency Ecological Program et al. 2022).

  Potential changes to Sacramento splittail, Sacramento hitch, and hardhead from seasonal operations During the December through May period for adult migration and spawning for average flows in the San Joaquin at Vernalis the CalSim 3 modeling results show that throughout the full simulation period flows are lower under Alternative 3 for most months compared to the No Action Alternative. Under Alternative 3 average flows in the San Joaquin at Vernalis ranged from 2,700 cfs (December) to 6,507 cfs (February) (Table O-263). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 16% reduction (April) to a 1% increase (February) for the full simulation period and for months December through May (Table O-263). With flows being lower during the native minnow spawning and migration period, and substantial reductions in the crucial month of April and for all water year types, Alternative 3 would likely have a negative effect as compared to the No Action Alternative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the San Joaquin at Vernalis under Alternative 3 range from 1,171 cfs (August) to 6,507 cfs (February) (Table O-263). The difference in average flows under Alternative 3 compared to the No Action Alternative had a range from a 20% reduction (July) to a 1% increase (February) for the full simulation period, and all months (Table O-263). Presence of native minnows in the San Joaquin are not well known, but it is likely that many species are present year-round. With reduction in flows occurring most months, and substantial reduction in flow during the fall, the effect of Alternative 3 would likely be negative for native minnows in the San Joaquin as compared to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on native minnows in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Based off the CalSim 3 flow analysis flows under Alternative 3 would be generally lower in the San Joaquin compared to the No Action Alternative. Many native minnows likely use the San Joaquin and its tributaries for spawning and rearing, adequate flow is also necessary for spawning adults to access spawning areas. With a substantial reduction in flow, impacts to native minnow under Alternative 3 compared to the No Action Alternative would be likely be negative for native minnows in the San Joaquin. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.6.16.6 Bay-Delta

Hardhead, Sacramento Hitch, and Sacramento Splittail

- **Hardhead:** The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are present in low abundance in the San Francisco Estuary and Delta. Brown and Michniuk (2007) electrofished parts of the Bay-Delta in the 1980's and 2000's and captured small numbers of hardhead. Retrieval of hardhead at the SWP/CVP south Delta fish salvage facilities remain relatively low (California Department of Water Resources 2020).
- **Sacramento Hitch:** The species is distributed in the Sacramento River Basin, in low numbers in the San Joaquin River Basin, and occasionally captured during monitoring programs in the Delta (Moyle et al. 2015; Interagency Ecological Program et al. 2022). Monitoring data suggests year round presence in the Delta (Interagency Ecological Program et al. 2022).
- **Sacramento Splittail:** Adult Sacramento splittail typically migrate upstream from brackish areas in January and February and spawn in freshwater, particularly on inundated floodplains when they are available, in March and April (Sommer et al. 1997; Moyle et al. 2004; Sommer et al. 2008). A substantial amount of splittail spawning occurs in the Yolo and Sutter Bypasses and the Cosumnes River area of the Delta (Moyle et al. 2004).

Although juvenile Sacramento splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks or months of rearing in floodplain habitats along the rivers (Feyrer et al. 2006). Juveniles move downstream into the Delta from April to August (Meng and Moyle 1995; Feyrer et al. 2005). Sacramento splittail recruitment is largely limited by extent and period of inundation of floodplain spawning habitats, with abundance observed to spike following wet years and dip after dry years (Moyle et al. 2004).

Potential Changes to Sacramento Splittail, Sacramento Hitch, and Hardhead from Seasonal Operations

CalSim 3 Flows

For many species of native minnow, it has been shown that changes in export flows can lead to higher levels of entrainment which can potentially influence population dynamics. Certain species such as Sacramento splittail are known to utilize the Delta for many portions of their life history so flows into the Delta will have a strong effect on these fish by limiting habitat, prey availability and access to spawning areas. Since many native minnows occupy the Delta year-round, flows and exports were examined for all months of the year.

During all months and for the full simulation period, CalSim 3 estimates of average Delta outflow would be higher under Alternative 3 for most months compared to the No Action Alternative. CalSim 3 estimates of average Delta outflow for all months have a range from 6,701 cfs (August) to 62,037 cfs (February) for Alternative 3 and for the full simulation period (Table O-254). Differences in average outflow under Alternative 3 as compared to the No Action Alternative would be from a 4% reduction (June) to a 42% increase (August) for the full simulation period and all months (Table O-254). With overall higher flows for most months, and dry water year types, the effect of Alternative 3 would be positive for native minnows as compared to the No Action Alternative.

CalSim 3 estimates of mean monthly average flow for the total exports of SWP and CVP under Alternative 3 for the full simulation period, and all months, range from 1,285 cfs (May) to 5,826 cfs (February) (Table O-253). The range of average export flow difference under Alternative 3 compared to the No Action Alternative for the full simulation period, and all months, were from a 15% reduction in exports (October) to a 69% decrease in exports (May) (Table O-253). With a few exceptions, exports would be substantially lower under Alternative 3, with less exports, entrainment would be expected to be less, and the effect would be positive for native minnows as compared to the No Action Alternative.

Summary

With overall higher flows for most months, and dry water year types, the impact of Alternative 3 would be beneficial for native minnows as compared to the No Action Alternative. With a few exceptions, exports would be substantially lower under Alternative 3, with less exports, entrainment would be expected to be less, and the impact would be beneficial for native minnows as compared to the No Action Alternative. Overall, changes to seasonal operations under Alternative 3 would likely see a strong beneficial impact for native minnows in the Bay-Delta region ass compared to the No Action Alternative.

Potential Changes to Entrainment of Sacramento Splittail, Sacramento Hitch, and Hardhead

Differences in exports under Alternative 3 compared with the No Action Alternative may have effects on native minnows entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density model.

Sacramento Splittail: Salvage Density

Predictions from the salvage density model for Sacramento splittail include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of Sacramento splittail at SWP Banks Pumping Plant for all months of the year and all water year types Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for all but critically dry water year types, with up to 53% lower for wet water year types and 2% higher for critically dry water year types (Table O-106). Predicted average monthly loss of Sacramento splittail at CVP Jones Pumping Plant for all months of the year and all water year types Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for all water year types. For all water year types Alternative 3 as compared to the No Action Alternative at Jones had a range from up to 87% lower for dry water year types to 56% lower for critically dry water year types, it should also be noted that in critically dry water year types predicted loss only occurred for six months of the year (Table O-107). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Sacramento Hitch: Salvage Density

Predictions from the salvage density model for Sacramento hitch include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of Sacramento hitch at SWP Banks Pumping Plant for all months of the year and all water years Alternative 3 was lower than predicted average monthly loss under the No Action Alternative for wet and below normal water year types, predicted loss was higher for above normal, and dry water year types, and there was no predicted loss for critically dry water year types. Predicted average monthly loss at Banks under Alternative 3 had a range from 65% lower for wet water year types to 39% higher for above normal water years (Table O-110). Predicted average monthly loss of Sacramento hitch at CVP Jones Pumping Plant for the months of March through April and all water year types Alternative 3 was lower than predicted average monthly loss under the No Action Alternative. The range of predicted loss for Sacramento hitch at Jones under Alternative 3 compared to the No Action Alternative was from 85% lower in above normal water year types to 32% lower for below normal water year types, no fish were predicted to be lost in dry and critically dry water year types. It should be noted that loss of Sacramento hitch at both facilities is rare and infrequent, with such low values of predicted loss, the percent differences may not be representative. (Table O-111). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Hardhead: Salvage Density

Predictions from the salvage density model for hardhead include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Whereas at the CVP Jones Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of hardhead of Alternative 3 compared to the No Action Alternative at the SWP Banks Pumping Plant was similar or lower all water year types, except in wet water years when it would be up to 65% lower and below normal and dry water year types when no fish are expected (Tables O108 and O-109). At the SWP Banks Pumping Plant predicted average monthly loss was between 39% and 372% greater in April of above normal water years and September of critically dry water years, respectively (Table O-108). Historical loss of hardhead at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Summary

In general, lower exports are predicted for Alternative 3, with less pumping in both the state and federal facilities entrainment and predicted salvage are lower for most months and water year types. Predicted loss at both facilities under Alternative 3 for native minnows would be generally lower, with some water year types having substantial reductions in salvage for native minnows as compared to the No Action Alternative.

O.6.17 Pacific Lamprey

O.6.17.1 Trinity River

Spawning and Egg Incubation

Pacific lamprey typically spawn from March through June, when daily mean water temperatures range from 50–64°F, with peak spawning occurring typically occurring in April and May and when water temperatures are approximately 57–59°F (Stone 2006, Brumo et al. 2009). Redds are typically constructed in gravel and cobble substrates within pool and run tailouts and low gradient riffles (Stone 2006, Brumo et al. 2009). Eggs are deposited in the redd and hatch after approximately 15 days, depending on water temperatures (Meeuwig et al. 2005, Brumo 2006). Egg-sac larvae spend another 15 days in redds before emergence. Temperatures in excess of 65°F during incubation have been shown to reduce embryo survival (Meeuwig et al. 2005). The effects analysis period for spawning and egg incubation in the Trinity River is March through July.

Potential Changes to Pacific Lamprey from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 to flows under the No Action Alternative during spawning and egg incubation periods for Pacific lamprey. Differences in monthly average flows between Alternative 3 and the No Action Alternative greater than 5% in reduction of flows would occur in March in below normal years and April in wet years (Table O-246). Under Alternative 3 compared to the No Action Alternative, flow decreases would occur during the Pacific lamprey spawning and egg

incubation period. The reduction in flows in wet and below normal years would likely be minor for spawning habitat and egg incubation as flows would remain above 400 cfs.

The flow decreases in March in below normal water years and April in wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17). Modeled monthly average water temperatures under Alternative 3 would remain well below the upper water temperature threshold for Pacific lamprey spawning and egg incubation of 65°F in the reach from Lewiston Dam to the North Fork Trinity River (Assarian et al. 2023). Similarly, the flow increases in December in below normal water years and February in above normal water years would cause only negligible changes in water temperature and there would be no change in the water temperature suitability for Pacific lamprey spawning and egg incubation relative to the No Action Alternative.

Ammocoete Rearing and Emigration

After emergence from redds, eyeless Pacific lamprey larvae, known as ammocoetes, settle out of the water column and burrow into fine silt and sand substrates, often containing organic matter. Ammocoetes rear in these habitats for four to 10 years. Water temperature requirements for the life stage are not well described. Ammocoetes have been observed burrowed in substrates in streams with water temperatures up to 80°F (Claire 2004), and upper temperature tolerances are estimated to be around 83°F (Whitesel and Uh 2022). After Pacific lamprey metamorphose to the macropthalmia stage, individuals migrate to the ocean typically in conjunction with high flow events between fall and spring, but can occur year-round. The effects analysis period for ammocoete rearing is year-round and emigration is primarily fall through spring in the Trinity River.

Potential Changes to Pacific Lamprey from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 to flows under the No Action Alternative during ammocoete rearing and emigration periods for Pacific lamprey. Differences in monthly average flows between Alternative 3 and the No Action Alternative greater than 5% in reduction of flows would occur in April of wet years (Table O-246). Under Alternative 3, monthly average flows would be almost identical to the No Action Alternative from April through November and will correspond to the No Action Alternative flows currently are managed to improve habitat conditions for anadromous fish. Increases in flow greater than 5% are modeled to occur in winter months in wet years, February in above normal years, and December in below normal years. Increases in flow would range from 65 to 135 cfs and would likely provide minor benefits to peak emigration periods of Pacific lamprey. Alternative 3 monthly average flows will have negligible to minor beneficial impacts on ammocoete rearing and emigration of Pacific lamprey when compared to the No Action Alternative even under reduced flows in wet years.

The flow increases in December, January, and February of wet water years, flow decreases in March in below normal water years and April in wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17). Modeled monthly average water temperatures under Alternative 3 would remain well below the upper water temperature threshold for Pacific lamprey ammocoete and emigration of 83°F in the

reach from Lewiston Dam to the North Fork Trinity River (Assarian et al. 2023). Similarly, the flow increases in December in below normal water years and February in above normal water years would cause only negligible changes in water temperature and there would be no change in the temperature suitability for Pacific lamprey ammocoete rearing and emigration relative to the No Action Alternative.

Adult Upstream Migration and Holding

Adult Pacific lamprey typically enter freshwater from winter to early summer, but in the Klamath River adults have been reported to enter year-round (Petersen-Lewis 2009, Parker 2018). In general, adult Pacific lampreys have two life history types: ocean maturing where individuals likely spawn several weeks after entering freshwater, and stream maturing where individuals spend one year in freshwater prior to spawning (Clemens et al. 2013, Parker et al. 2019). In general, adult Pacific lamprey hold in interstitial spaces within large cobble and boulders and also in glides, runs, and riffles (Lampman 2011). Water temperature requirements for holding adult Pacific lampreys have not been fully evaluated, but adults have been observed in temperatures ranging from 60 to 84°F (Starecvich et al. 2014). The effects analysis period for adult upstream migration and holding in the Trinity River is year-round.

Potential Changes to Pacific Lamprey from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam would generally be similar to higher under Alternative 3 to flows under the No Action Alternative during adult upstream migration and holding periods for Pacific lamprey. Differences in monthly average flows between Alternative 3 and the No Action Alternative greater than 5% in reduction of flows would occur in April of wet years (Table O-246). Under Alternative 3, monthly average flows would be almost identical to the No Action Alternative from April through November and will correspond to the No Action Alternatives flows currently are managed to improve habitat conditions for anadromous fish. Increases in flow greater than 5% are modeled to occur in winter months in wet years, February in above normal years, and December in below normal years. Increases in flow would range from 65 to 135 cfs and would likely provide minor benefits to winter and negligible impacts to spring/summer emigration periods of Pacific lamprey.

The flow increases in December, January, and February of wet water years, flow decreases in March in below normal water years and April in wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17). Modeled monthly average water temperatures under Alternative 3 would remain well below the upper water temperature suggested for Pacific lamprey adult upstream migration and holding of 84°F in the reach from Lewiston Dam to the North Fork Trinity River (Assarian et al. 2023). Similarly, the flow increases in December in below normal water years and February in above normal water years would cause only negligible changes in water temperature and there would be no change in the temperature suitability for Pacific lamprey adult upstream migration and holding relative to the No Action Alternative.

O.6.17.2 Sacramento River

Spawning and Egg Incubation

Pacific lamprey construct redds in shallow water (about 0.5 to 3.5 feet or 0.15 to 1 meter) gravel habitats in the upper river and spawning occurs from March through July with peak spawning typically occurring in early April (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015). The eggs and pro-larvae incubate for about one to 1.5 months. Water flows and water temperature impacts on eggs occur between March–August but are primarily between April–May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam for Alternative 3 are a mix of increases and decreases compared to the No Action Alternative (Table O-248 and Table O-249). Impacts on Pacific lamprey spawning and egg incubation are likely to be mixed as well. Both locations are expected to see large increases in flow during wet and above normal years in May, but also large decreases for many water-year types April through July. While the increases in wet years could have beneficial impacts, much of the spawning period would likely see some adverse impacts from flow decreases. Both locations would see flow increases in below normal and dry years in August, which could have beneficial impacts on egg incubation, but spawning would likely not be impacted, as this is at the very end of the spawning period and impacts would more likely be on eggs previously laid. Flows during the spawning period are expected to remain high enough that redds should not be dewatered, which should prevent serious adverse impacts on spawning. However, large flow decreases for most water-year types during spawning months would likely have minor adverse impacts on spawning and egg incubation.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 295 for Keswick Dam and Table 296 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-112. Table O-112, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were zero and two month-water year type combinations (0% and 8.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-112). There were zero and one combinations (0% and 4.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be negligible water temperature-related

impacts of Alternative 3 on Pacific lamprey spawning and egg incubation in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey spawning and egg incubation in the Sacramento River due to differences in water temperature.

Ammocoete Rearing and Emigration

After Pacific lamprey larvae (ammocoetes) emerge, they drift downstream and burrow into fine sediments to rear. Ammocoetes select habitats that are often off-channel, with low flow velocity and shallow depths; therefore, they are vulnerable to stranding by reductions in water level. After three or more years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean. Data from rotary screw trapping at sites on the mainstem Sacramento River indicate that emigration of Pacific lamprey peaks from early winter through early summer, but some emigration is observed year-round at both the RBDD and the GCID diversion dam (Hanni et al. 2006).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam are a mix of increases and decreases compared to the No Action Alternative (Table O-248 and Table O-249). Impacts on Pacific lamprey ammocoete rearing and emigration are likely to be mixed as well. Ammocoete rearing will likely see both positive and negative effects, as flows increase and decrease depending on month and water-year type. The largest impacts would likely be during dry and critically dry years, when flows are at their lowest. Smaller increases in some fall and winter months would likely benefit ammocoetes in these years, but some spring and summer decreases could prove adverse. Flows are expected to remain high enough that ammocoete survival should not be threatened in these years, so overall impacts are likely to be minor but a mixture of beneficial and adverse. Juvenile emigration is likely to see similarly minor but mixed impacts. Flows are expected to remain high enough that survival should not be threatened, but fairly large changes in flow compared to the No Action Alternative are likely to have both beneficial and adverse impacts.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific Lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 298 for Keswick Dam and Table 299 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-113. Table O-113, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results at both Keswick Dam and RBDD (Table O-113). These results suggest that there would be negligible water temperature-related impacts of Alternative 3 on Pacific lamprey ammocoete rearing and emigration in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor adverse to minor beneficial impacts on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration in the Sacramento River due to differences in water temperature.

O.6.17.3 Clear Creek

Spawning and Egg Incubation

Pacific lamprey usually spawn in Clear Creek from March through July, depending on water temperatures and local conditions such as seasonal flow regimes. The adults construct redds similar to steelhead redds, and eggs incubate for 11 to 30 days, depending on the water temperature, prior to hatching. Although the extent of spawning is unknown, the species spawns in Clear Creek as evidenced by ammocoetes routinely collected in the screw trap at RM 1.7. Effects from water flows and temperature on eggs are likely felt March-August, and they likely peak in accordance with peak spawning April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in Clear Creek below Whiskeytown Dam under Alternative 3 would see a mix of increases and decreases compared to the No Action Alternative depending on month and water year type (Table O-257). Impacts of these flow changes on Pacific lamprey spawning would likely be mixed, with positive impacts from flow increases during the peak spawning period in March, April and May, but flow decreases during some or all water year types for February and June through August, which could have adverse impacts on the beginning and end, respectively, of the spawning period. Overall the impacts of flow changes from Alternative 3 compared to the No Action Alternative would be mixed.

Water Temperature Analysis

Potential water temperature-related impacts to Pacific lamprey spawning and egg incubation in Clear Creek were evaluated by assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey (Meeuwig et al. 2003, 2005) below Whiskeytown Dam (Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 2).

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 288 for Clear Creek below Whiskeytown Dam.

Results for the analysis are summarized in Table O-114. Table O-114, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were eight month-water year type combinations (33.3% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable results below Whiskeytown Dam (Table O-114). These results suggest that there would be positive water temperature-related impacts of Alternative 3 on Pacific lamprey spawning and egg incubation in Clear Creek.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have beneficial impacts on Pacific lamprey spawning and egg incubation due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey rearing takes place over a matter of years. Hatched embryos remain in the gravel for up to one more month as gill slits develop. The ammocoetes then spend three to seven years in soft sediments as filter feeders (USFWS 2019). Once ammocoetes have become juveniles, they begin to migrate towards the ocean in spring and possibly early summer. Impacts from water temperature and flow on larval and juveniles are year-round due to their prolonged rearing in their home waters, with spring and summer flows during migratory periods being important as well.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in Clear Creek below Whiskeytown Dam under Alternative 3 would see a mix of increases and decreases compared to the No Action Alternative (Table O-257). Impacts on Pacific lamprey ammocoete rearing would likely be mixed, as rearing takes place over several years, and positive impacts during months and water years with increased

flows would likely be balanced by negative impacts from those months and water year types with decreased flows. Juvenile emigration for Pacific lamprey would likely see some positive impacts under Alternative 3, as flows generally increase during the peak outmigration period in winter and spring months, with the exception of February, which sees flow decreases in wet, above normal, and below normal years.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific Lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 291 for Clear Creek below Whiskeytown Dam.

Results for the analysis are summarized in Table O-115. Table O-115, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-115). These results suggest that there would be negligible water temperature-related impacts of Alternative 3 on Pacific lamprey ammocoete rearing and emigration in Clear Creek.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey ammocoete rearing, and minor beneficial impacts on Pacific lamprey juvenile emigration due to differences in flow. Alternative 3 relative to the No Action Alternative are expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration due to differences in water temperature.

O.6.17.4 Lower American River

Spawning and Egg Incubation

Hannon and Deason (2008) documented Pacific lamprey spawning in the lower American River from early January to late May, with peak spawning typically occurring in early April. Redds are built in shallow water environments and eggs incubate for several weeks before larvae emerge. Water temperature and flow impacts on eggs are likely January-June, with peak impacts April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the lower American River at H Street and below Nimbus Dam under Alternative 3 would see a mix of increases and decreases compared to the No Action Alternative (Table O-259 and Table O-260). Impacts on spawning for Pacific lamprey would likely be mixed, with most water year types seeing flow increases for January through April,

during the beginning and middle of the spawning period, but with flow decreases for all water year types in June and some types for May. As May is within the peak spawning period, flow decreases in below normal and dry water years could have adverse impacts on Pacific lamprey spawning, and large flow decreases during June could have negative consequences on the end of the spawning period and eggs laid during the latter half of the peak spawning period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities during March through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 79 for Hazel Avenue and Table 80 for Watt Avenue.

Results for the analysis are summarized in Table O-116. Table O-116, as described in Section O.4.17.4.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities for Pacific lamprey spawning and egg incubation under Alternative 3, there were two and zero month-water combinations (8.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-116). There were one and two month-water combinations (4.0% and 8.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that Alternative 3 would have negligible water temperature-related impacts to Pacific lamprey spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey spawning and egg incubation due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey ammocoetes rear in the lower American River for all or part of their 3- to 7-year freshwater residence. Larvae spend a month maturing to ammocoetes before leaving spawning areas to find suitable rearing habitat, usually shallow, off-channel areas with low flow velocity where they will spend the next several years filter-feeding and maturing to juvenile stage. Once juveniles, they will begin migrating towards the ocean. Data from rotary screw trapping in the nearby Feather River suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006), although some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006) and in other river systems (Moyle 2002).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the lower American River at H Street and below Nimbus Dam under Alternative 3 would see a mix of increases and decreases compared to the No Action Alternative (Table O-259 and Table O-260). Impacts on Pacific lamprey ammocoete rearing would be mixed. As rearing takes place over several years, ammocoetes would feel the range of flow increases and decreases and the accompanying beneficial and adverse impacts. Lower flows in months such as June would likely have adverse impacts, while generally increased flows December through April would likely be beneficial. Impacts of flow changes on juvenile emigration would likely be similarly mixed, though more beneficial than adverse. As emigration occurs largely between winter and early summer, the aforementioned generally increased flows December through April would likely have a positive impact on outmigration. Conversely, decreased flows in some water year types for May and June are likely to have negative impacts on juvenile emigration.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 48 for Hazel Avenue and Table 50 for Watt Avenue.

Results for the analysis are summarized in Table O-117. Table O-117, as described in Section O.4.17.4.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific lamprey ammocoete rearing and emigration under Alternative 3, there were zero month-water combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-117). There were zero and four month-water combinations (0.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 3, there would be negligible water temperature-related impacts to Pacific lamprey ammocoete rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey ammocoete rearing, and minor adverse to minor beneficial impacts on Pacific lamprey juvenile emigration due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration due to differences in water temperature.

O.6.17.5 Stanislaus River

Spawning and Egg Incubation

Hannon and Deason (2008) have documented Pacific lampreys spawning in the lower American River from early January to late May, with peak spawning typically in early April. Spawning time is presumably similar in the Stanislaus River. Eggs are laid in redds constructed in shallow water, and incubation takes several weeks. Impacts from water flows and temperature on eggs are present February-June, likely with a peak April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Stanislaus River at the mouth and below Goodwin Dam under Alternative 3 will see a mix of increases and decreases depending on month and water year type (Table O-261 and Table O-262). Alternative 3 would possibly have a beneficial impact on spawning for Pacific lamprey in the Stanislaus River, as flows at both the mouth of the river and below Goodwin Dam would be increased relative to the No Action Alternative during the peak spawning period of April and May for most water year types. Flows are also increased for most of the non-peak months of the larger spawning period, February through June, with the exception of critically dry years, which would see some flow decreases. Overall, Pacific lamprey spawning should mostly benefit from flow changes due to Alternative 3.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities during April through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 62 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-118. Table O-118, as described in Section O.4.17.5, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 with TUCP without VA for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities of Pacific lamprey, there were no month-water year type combinations (0.0%) with favorable or unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-118).

These results suggest that Alternative 3 would have negligible water temperature related impacts on Pacific lamprey spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

Alternative 3 relative to the No Action Alternative is expected to have moderate beneficial to minor adverse impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey spawning and egg incubation due to differences in water temperature.

Ammocoete Rearing and Emigration

Pacific lamprey ammocoetes are expected to rear in the Stanislaus River for all or part of their three and seven year freshwater residence. Larvae usually spend a month in their spawning areas before becoming ammocoetes and moving to rearing habitat in shallow, off-channel areas. After several years, they become juveniles and migrate out to the ocean. Data from rotary screw trapping in the nearby Mokelumne and Tuolumne rivers suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006). Catches of juvenile Pacific lampreys in trawl surveys of the mainstem San Joaquin River, near the mouth of the Stanislaus River at Mossdale, occurred during winter and spring. Some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Stanislaus River at the mouth and below Goodwin Dam under Alternative 3 will see a mix of increases and decreases relative to the No Action Alternative depending on month and water year type (Table O-261 and Table O-262). Impacts on Pacific lamprey ammocoete rearing would likely be mixed. As rearing takes place over several years, ammocoetes would experience the flow increases and decreases from Alternative 3 (depending on month and water year type) and their accompanying impacts. Impacts on juvenile emigration would also likely be mixed, as flow decreases in most water year types between November and January would likely have an adverse impact on the beginning of the outmigration period, while flows mostly increase February through June, which would likely benefit emigrating Pacific lamprey juveniles.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 63 for Orange Blossom Bridge and Table 64 for the Stanislaus River above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-119. Table O-119, as described in Section O.4.17.5, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific lamprey, there were no month-water year type combinations (0.0%) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-119). There were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 3 would have negligible water temperature related impacts on Pacific lamprey ammocoete rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration due to differences in water temperature.

O.6.17.6 San Joaquin River

Ammocoete Rearing and Emigration

Once Pacific lamprey larvae emerge, they spend roughly a month in spawning areas before becoming ammocoetes and moving to rearing habitat in shallow, off-channel waters with low flow velocity, where they will spend the following several years (roughly 3-7) maturing to the juvenile stage. Once juveniles, they begin a migration towards the ocean. Midwater trawl surveys in the San Joaquin River suggest that peak ammocoete out-migration occurs in January and February (Hanni et al. 2006). Ammocoetes are vulnerable to habitat loss due to the nature of their rearing habitat.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 models predict that flows in the San Joaquin River at Vernalis under Alternative 3 would largely be decreased across months and water year types compared to the No Action Alternative (Table O-263). Pacific lamprey ammocoete rearing would likely be adversely impacted by these decreased flows. As ammocoete rearing takes place over several years, ammocoetes would experience flow decreases and the accompanying adverse impacts across months and likely water year types. Juvenile outmigration would similarly see some likely adverse impacts, as flows during winter and spring months, when emigration is highest, are decreased for almost every water year type compared to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on Pacific lamprey in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor adverse impacts on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.6.17.7 Bay-Delta

Some Pacific lamprey ammocoetes likely spend part of their extended (3 to 7 years) freshwater residence rearing in the Delta, particularly in the upstream, freshwater portions (California Department of Water Resources et al. 2013). Ammocoetes are present year-round in all of the regions (California Department of Water Resources et al. 2013). Data from the Fall Midwater Trawl Survey in the lower Sacramento and San Joaquin rivers and Suisun Bay suggest that peak out-migration of Pacific lamprey through the Delta coincides with high-flow events from fall through spring (Hanni et al. 2006). Water temperature and flows affect resident ammocoetes year

round and migrating juveniles fall-spring. Duration of estuarine adult migration and holding in the San Francisco Estuary is poorly understood, but some evidence suggests they may migrate as early as the fall and throughout the spawning season until late June (Moyle et al. 2015).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that Sacramento River flow in Rio Vista under Alternative 3 would see a mix of increases and decreases compared to the No Action Alternative (Table O-256). For impacts in the southern Delta, see the San Joaquin Rive section above, which discusses flow at Vernalis. Flows at Rio Vista under Alternative 3 are expected to increase compared to the No Action Alternative from December through May, while generally decreasing from June through September. Flows are likely adequate ammocoete rearing since they burrow and rear in sandy substrates and do not require high flows. Impacts on juvenile emigration and adult migration would likely be mixed, as flows increase in winter through early summer near Rio Vista in critically dry water year types but decrease in all other water year types June through August.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor adverse impacts and minor beneficial impacts on Pacific lamprey juvenile emigration due to differences in flow, depending on the month and water year type. Alternative 3 relative to the No Action Alternative is expected to have minor adverse impacts and minor beneficial impacts on adult migration due to differences in flow, depending on month and water year type. Impacts on ammocoete rearing are expected to be negligible.

Potential Changes to Entrainment of Pacific Lamprey

Differences in exports under Alternative 3 compared with the No Action Alternative may have impacts on Pacific lamprey entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for Pacific lamprey include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Pacific lamprey of Alternative 3 compared to the No Action Alternative at the CVP Jones Pumping Plant were lower all water year types (Tables O-120 and O-121). At the CVP Jones Pumping Plant predicted average monthly loss was up to 75 % lower for December through September of critically dry water year types (Table O-121). It should be noted that loss of Pacific lamprey is infrequent with such low values of predicted loss, the percentage differences may not imply significance at a population level.

Summary

Differences in exports between Alternative 3 and the No Action Alternative are expected to have substantially beneficial impacts on the entrainment of Pacific lamprey at CVP Jones Pumping Plant, but the species is infrequent at the facility. No impacts at the SWP Banks Pumping Plant are expected.

O.6.18 Western River Lamprey

O.6.18.1 Sacramento River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam for Alternative 3 are a mix of increases and decreases compared to the No Action Alternative (Table O-248 and Table O-249). Impacts on Western river lamprey spawning and egg incubation are likely to be mixed as well. Both locations are expected to see large increases in flow during wet and above normal years in May, but also large decreases for many water-year types April through July. While the increases in wet years could have beneficial impacts, much of the spawning period would likely see some adverse impacts from flow decreases. Both locations would see flow increases in below normal and dry years in August, which could have beneficial impacts on egg incubation, but spawning would likely not be affected, as this is at the very end of the spawning period and impacts would more likely be on eggs previously laid. Flows during the spawning period are expected to remain high enough that redds should not be dewatered, which should prevent serious adverse impacts on spawning. However, large flow decreases for most water-year types during spawning months would possibly have minor adverse impacts on Western river lamprey spawning and egg incubation.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Western river lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Keswick Dam and Table 305 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-122. Table O-122, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were five and zero month-water year type combinations (16.7% and 3.3% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-122). There were zero and one combination (0% and 3.3%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be positive water temperature-related impacts of Alternative 3 on Western river lamprey spawning and egg incubation in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts for Western river lamprey spawning and egg incubation due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have beneficial impacts on Western river lamprey spawning and egg incubation due to differences in water temperature.

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam are a mix of increases and decreases compared to the No Action Alternative (Table O-248 and Table O-249). Impacts on Western river lamprey ammocoete rearing and emigration are likely to be mixed as well. Ammocoete rearing will likely see both positive and negative impacts, as flows increase and decrease depending on month and water-year type. The largest impacts would likely be during dry and critically dry years, when flows are at their lowest. Smaller increases in some fall and winter months would likely benefit ammocoetes in these years, but some spring and summer decreases could prove adverse. Flows are expected to remain high enough that ammocoete survival should not be threatened in these years, so overall impacts are likely to be minor but a mixture of beneficial and adverse. Juvenile emigration is likely to see similarly minor but mixed impacts. Flows are expected to remain high enough that survival should not be threatened, but fairly large changes in flow compared to the No Action Alternative are likely to have both beneficial and adverse impacts.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Western river lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Keswick Dam and Table 305 for Red Bluff Diversion Dam.

Results for the three analyses are summarized in Table O-123. Table O-123, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results at both Keswick Dam and RBDD (Table O-123). These results suggest that there would be negligible water temperature-related impacts of Alternative 3 on Western river lamprey ammocoete rearing and emigration in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor adverse to minor beneficial impacts on Western river lamprey ammocoete rearing and emigration due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Western river lamprey ammocoete rearing and emigration due to differences in water temperature.

O.6.18.2 Lower American River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 3 see some increases in winter and spring months but also see some decreases in summer months compared to the No Action Alternative (Table O-259 and Table O-260). Impacts on Western river lamprey spawning are likely to be mixed, with flow increases in March and April likely being beneficial to the start of the spawning period, while large flow decreases in June and July having adverse impacts. Decreases in June could also affect some eggs laid in May during the peak spawning period. Overall impacts are likely to be mixed, with beneficial and adverse impacts in the spawning period largely dependent on month and water year type.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in Western river lamprey during February through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 83 for Hazel Avenue and Table 84 for Watt Avenue.

Results for the analysis are summarized in Table O-124. Table O-124, as described in Section O.4.18.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in Western river lamprey spawning and egg incubation under Alternative 3, there were two and one month-water combinations (6.7% and 3.3%, respectively) with favorable results at both Hazel Avenue and Watt Avenue (Table O-124). There were one and three month-water combinations (3.3% and 10.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that Alternative 3 would have negative and positive water temperature-related impacts to Western river lamprey spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to minor adverse impacts on Western river lamprey spawning and egg incubation due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have adverse and beneficial impacts on Western River lamprey spawning and egg incubation due to differences in water temperature.

Ammocoete Rearing and Emigration

Western River lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 3 see some increases in winter and spring months but also see some decreases in summer months compared to the No Action Alternative (Table O-259 and Table O-260). Impacts on Western river lamprey ammocoete rearing are likely to be mixed. Flow increases in spring months would likely be beneficial to ammocoetes, but flow decreases in

summer and some fall water year types would likely have an adverse impact. The greatest impact might be in November of critically dry years, when flows are expected to decrease compared to the No Action Alternative and reach some of the lowest levels of the year (826 cfs at the lower American River at H Street). This could have an adverse impact on ammocoetes. Impacts on juvenile emigration would likely be mixed as well. The same decrease in critically dry years in November could adversely affect emigration, while flow increases in March and April could prove beneficial. Overall impacts on emigration then are likely to be mixed.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 85 for Hazel Avenue and Table 86 for Watt Avenue.

Results for the analysis are summarized in Table O-125. Table O-125, as described in Section O.4.18.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey ammocoete rearing and emigration under Alternative 3, there were zero month-water combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-125). There were zero month-water combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that under Alternative 3, there would be negligible water temperature-related impacts to Western river lamprey ammocoete rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial to moderate adverse impacts on Western river lamprey ammocoete rearing and emigration due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Western river lamprey ammocoete rearing and emigration due to differences in water temperature.

O.6.18.3 Stanislaus River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates of monthly flows in the Stanislaus River at the mouth and below Goodwin Dam for Alternative 3 compared to the No Action Alternative are generally increased from February through June but see decreases in some water year types August through January (Table O-261 and Table O-262). Impacts on Western river lamprey spawning are likely beneficial. Increased flows for most water year types during the first half, and the peak of the spawning period would likely have beneficial impacts. The exception to this would be in critically dry years, which see little to no change during February through June. The end months of the spawning period, July and August, have some small changes, but the greatest overall impacts would be from the increases in flow in most water year types during the spawning period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in Western river lamprey during February through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 65 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-126. Table O-126, as described in Section O.4.18.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities of Western river lamprey, there were zero month-water year type combinations (0.0%) with favorable results and three combinations (10.0%) with unfavorable results at Orange Blossom Bridge (Table O-126).

These results suggest that Alternative 3 would have negative water temperature related impacts on Western river lamprey spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

Alternative 3 relative to the No Action Alternative is expected to have beneficial impacts on Western river lamprey spawning and egg incubation due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have adverse impacts on Western River lamprey spawning and egg incubation due to differences in water temperature.

Ammocoete Rearing and Emigration

Western River lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates of monthly flows in the Stanislaus River at the mouth and below Goodwin Dam for Alternative 3 compared to the No Action Alternative are generally increased from February through June, but see decreases in some water year types August through January (Table O-261 and Table O-262). Impacts on Western river lamprey ammocoete rearing are likely to be mixed. Flow increases during spring and early summer months could be beneficial to ammocoetes, who are present for several years, but decreases in flows during fall and winter could provide adverse impacts. The greatest concern might be July through September in critically dry years, which see small decreases in flows; however, flows under the No Action Alternative are already expected to be very low, so decreases could threaten serious adverse impacts, and increase the risk of ammocoete mortality. Impacts of flow changes on juvenile emigration are likely to be mixed. Decreases in the early winter months could have adverse impacts, especially in drier years when flows are expected to be among the lowest year-round. Conversely, flows increase from February through June, which would be beneficial to emigration.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 66 for Orange Blossom Bridge and Table 67 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-127. Table O-127, as described in Section O.4.18.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Western river lamprey, there were no month-water year type combinations (0.0%) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-127). There were zero to one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 3 would have negligible water temperature related impact on Western river lamprey ammocoete rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have beneficial and adverse impacts on Western River lamprey ammocoete rearing and emigration due to differences in flow. Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on Western River lamprey ammocoete rearing and emigration due to differences in water temperature.

O.6.18.4 San Joaquin River

Ammocoete Rearing and Emigration

Western River lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 estimates for monthly flows in the San Joaquin River at Vernalis for Alternative 3 are largely decreased compared to the No Action Alternative (Table O-263). The impact on Western river lamprey ammocoete rearing would likely be adverse. Decreases in flows during summer months in critically dry years could have an adverse impact on ammocoete rearing, even possibly leading to their exposure and the drying of the sediments that ammocoetes remain buried in during maturation. Other impacts would depend on water year type, but would likely be mostly adverse, though only dry and critically dry summer months would have the risk of mortality events for ammocoetes. Impacts of changes in flows from Alternative 3 on juvenile emigration would likely be minimal. Flow decreases during the winter and spring months are expected to be small, and outmigration would likely not be affected. April could see some adverse impacts on emigration as flows decrease in all water year types, but juveniles should still be able to emigrate.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on Western river lamprey in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

<u>Summary</u>

Alternative 3 relative to the No Action Alternative is expected to have adverse impacts on Western River lamprey ammocoete rearing and emigration due to differences in flow. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.6.18.5 Bay-Delta

The Sacramento and San Joaquin River Basins are at the southern edge of the range for Western river lamprey (Moyle et al. 2009). While their population abundance is poorly understood, they are frequently caught in the Delta Juvenile Fish Monitoring Program in the winter months through trawls at Sherwood Harbor, Mossdale, and Chipps Island (Interagency Ecological Program et al. 2022). Ammocoetes spend an unknown amount of time as ammocoetes (likely 3-5 years) in silt-sand backwater eddies and have been documented during dredging studies in the Delta (Lamprey Technical Workgroup 2021; Moyle et al. 2015). Adults typically start their migration back into their natal habitats in the fall.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Bay-Delta under Alternative 3 would see a mix of increases and decreases compared to the No Action Alternative (Table O-256). For impacts in the southern Delta, see the San Joaquin River section above, which discusses flow at Vernalis. Flows at Rio Vista under Alternative 3 are expected to increase compared to the No Action Alternative from December through May, while generally decreasing from June through September. Impacts on Western river lamprey ammocoete rearing are expected to be negligible, as flows are adequate for rearing in the sandy substrate. Juveniles emigrating through the Delta would experience decreased flows in summer months closer to Rio Vista in most water year types and increased flows in critically dry water year types under Alternative 3. Adults migrating through the Sacramento River at Rio Vista would experience decreased flows in September of critically dry water year types under Alternative 3.

Summary

Alternative 3 relative to the No Action Alternative is expected to have minor beneficial and adverse impacts on Western River lamprey juvenile emigration due to differences in flow, depending on the water year type. Alternative 3 relative to the No Action Alternative is expected to have adverse impacts on adult migration in September of critically dry water year types due to differences in flow.

Potential Changes to Entrainment of Western River Lamprey

Salvage Density

Predictions from the salvage density model for Western river lamprey include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Western river lamprey of Alternative 3 compared to the No Action Alternative at the CVP Jones Pumping Plant were similar or lower for all water year types, except dry water year types when no fish are expected (Tables O-128 and O-129). At the CVP Jones Pumping Plant predicted average monthly loss was up to 61 % lower for February through March of critically dry water year types (Table O-129). Historical loss of Western River is infrequent; this is a driver of low values of predicted loss.

Summary

Differences in exports between Alternative 3 and the No Action Alternative are expected to have generally beneficial impacts on the entrainment of Western river lamprey at CVP Jones Pumping Plant, but the species is infrequent at the facility. No impacts at the SWP Banks Pumping Plant are expected.

O.6.19 Striped Bass

O.6.19.1 Sacramento River

Spawning and Egg Incubation

It is believed that striped bass do not spawn or rear in the Sacramento River upstream of RBDD (Tehama-Colusa Canal Authority 2008). Most spawning in the Sacramento River occurs in the lower river between Colusa and the confluence of the Sacramento and Feather Rivers (Moyle 2002). About one-half to two-thirds of adults spawn in the Sacramento River and the remainder spawn in the Delta (Leet et al. 2001). After spawning, most adult striped bass move downstream into brackish and salt water for summer and fall (Moyle 2002).

Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

Potential Changes to Striped Bass from Seasonal Operations

<u>CalSim 3 Flows</u>

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows at Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤ 5%) increase or decrease is estimated most months except May (higher [≥6%]), June (lower [≥6%]). This suggests minor adverse impacts on striped bass, although habitat will generally remain similar under Alternative 3 compared to the No Action Alternative (Table O-249 through Table O-251).

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 68°F optimal water temperature range for spawning, embryo incubation and initial rearing for striped bass during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 317 for Butte City.

Results for the analysis are summarized in Table O-130. Table O-130, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 59°F to 68°F optimal water temperature range, there was one month-water year type combination (6.7% of total combinations during the period) with favorable results at Butte City (Table O-130). There were three combinations (20.0%) with unfavorable results at Butte City. These results suggest that there would be negative and negligible positive water temperature-related effects of Alternative 3 on striped bass spawning and egg incubation in the Sacramento River.

Summary

Overall, under Alternative 3 compared to the No Action Alternative for CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will generally remain largely similar to the No Action Alternative, with some slight adverse impacts on striped bass habitat. The optimal water temperature range modeling estimates indicate 6.7% month-water year type combinations with favorable and 20% combinations with adverse results at Butte City. Overall, these results suggest that there would be minor adverse flow impacts for spawning habitat and water temperature-related impacts on striped bass spawning and egg incubation in the Sacramento River under Alternative 3.

Laval and Juvenile Rearing and Emigration

During this early period the embryos and larvae in the Sacramento River are carried into the Delta and Suisun Bay (Moyle 2002). YOY striped bass distribute themselves in accordance with the estuarine salinity gradient (Kimmerer 2002a; Feyrer et al. 2007), indicating that salinity is a major factor affecting their habitat use and geographic distributions. Kimmerer (2002a) found that distributions of fish species, including striped bass, substantially overlapped with the low-salinity zone. Older individuals are increasingly flexible about their distribution relative to salinity (Moyle 2002). Statistically significant correlations between indices of age-0 abundance or survival in the San Francisco Estuary and Delta have been found with Delta outflow (which can be approximated by X2, the distance in km from the Golden Gate Bridge at which bottom salinity is 2 psu) (e.g., Kimmerer et al. 2009; Mac Nally et al. 2010), with evidence for greater extent of habitat as the mechanism (Kimmerer et al. 2009). However, subsequent density-dependent survival after the first summer dampens the effects of flow on subsequent recruitment (Kimmerer et al. 2000).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows at Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (<5%) increase and/or decrease is estimated most months except May (higher), June (lower), July (lower), August (higher, Wilkins Slough and Hamilton City), and September (lower, Wilkins Slough); this suggests negligible impacts on striped bass, as habitat will generally remain largely similar to the No Action Alternative (Table O-249 through Table O-251).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F range of optimal temperatures for larvae, fry, and juvenile rearing and emigration year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 318 for Butte City.

Results for the analysis are summarized in Table O-131. Table O-131, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 61°F to 71°F optimal water temperature range for larvae, fry, and juvenile rearing and emigration, there were four month-water year type combinations (6.7% of total combinations during the period) with favorable results at Butte City (Table O-131). There were three month-water year type combinations (5.0% of total combinations during the period) with favorable results at Butte City. These results suggest that there would be positive and negative water temperature-related impacts from Alternative 3 on striped bass larvae, fry, and juvenile rearing and emigration in the Sacramento River.

Summary

Overall, under Alternative 3 compared to the No Action Alternative for CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests impact to striped bass spawning habitat extent will be negligible. The optimal water temperature range modeling estimates indicate 6.7% month-water year type combinations with beneficial and 5% combinations with adverse results at Butte City. Overall, these results suggest there would be negligible flow impacts and minor beneficial and adverse water temperature-related impacts on striped bass juvenile rearing and emigration habitat extent in the Sacramento River under Alternative 3.

O.6.19.2 Lower American River

Adults

Striped bass are present in the lower American River throughout the year, with the greatest abundance in summer (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam and in the lower American River at H Street indicate that minor (≤ 5%) increase and/or decrease is estimated nearly half of the months (Table O-259 and Table O-260). Below Nimbus Dam, slight (12%, June) moderate (27%, June) decreases are expected an average 3 months out of year; slight (≤ 10%, March and August) and moderate (16%, April) increases are expected. At H street, slight (≤ 11%, March and August) and moderate (16%, April) increases are expected an average 3 months out of year; slight (13%, June) and moderate (29%, June) increases are expected. These results suggest potential adverse impacts on striped bass at below Nimbus Dam and beneficial impacts at H street, generally in June and July.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F stress initiation value for adult striped bass year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 93 for Hazel Avenue and Table 94 for Watt Avenue.

Results for the analysis are summarized in Table O-132. Table O-132, as described in Section O.4.19.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 77°F stress initiation water temperature value for adult striped bass under Alternative 3, there were zero month-water combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-132). There were also zero month-water combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue.

These results suggest that under Alternative 3, there would be negligible water temperature-related impacts to adult striped bass in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Overall, under Alternative 3 compared to the No Action Alternative CalSim 3 flow and water temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests flow impacts on striped bass spawning habitat extent may experience slight to moderate beneficial and adverse impacts in June and July. The optimal water temperature range modeling estimates indicate there are no combinations with beneficial or adverse results at Butte City. Overall, these results suggest there would be generally beneficial and adverse flow impacts on adult habitat and negligible water temperature-related impacts to adult striped bass in the lower American River at Hazel Avenue and Watt Avenue under Alternative 3 compared to the No Action Alternative.

Juvenile Rearing

Although the occurrence of spawning in the lower American River is uncertain, the river is believed to serve as a nursery area for YOY and subadult striped bass (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam and H Street indicate that minor (≤ 5%) increase and/or decrease is estimated nearly half of the months (Table O-259 and Table O-260). Below Nimbus Dam, slight (12%, June) moderate (27%, June) decreases are expected; slight (≤ 10%, March and August) and moderate (16%, April) increases are expected. At H street, slight (≤ 11%, March and August) and moderate (16%, April) increases are expected; slight (13%, July) and moderate (29%, June) decreases are expected. These results suggest adverse impacts on striped bass may occur below Nimbus Dams and beneficial impacts at H street, generally in June and July.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 95 for Hazel Avenue and Table 96 for Watt Avenue.

Results for the analysis are summarized in Table O-133. Table O-133, as described in Section O.4.19.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 61°F to 71°F optimal range for juvenile striped bass rearing under Alternative 3, there were four and three month-water combinations (6.7% and 5.0%, respectively) with favorable results at both Hazel Avenue and Watt Avenue (Table O-133). There were zero and six month-water combinations (0% and 10.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 3, there would be positive and negative water temperature-related impacts to juvenile striped bass rearing in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Overall, under Alternative 3 compared to the No Action Alternative CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests flow impacts on striped bass spawning habitat extent may experience slight to moderate beneficial and adverse impacts in June and July. The optimal water temperature range modeling estimates indicate 6.7% and 5% beneficial month-water year type combinations at Hazel Avenue and Watt Avenue (respectively) and 10% adverse combinations at Watt Avenue in the lower American River. Overall, these results suggest there would be beneficial and adverse flow impacts on juvenile rearing habitat and beneficial (Hazel Avenue) and adverse (Watt Avenue) water temperature-related impacts to juvenile striped bass rearing in the lower American River.

O.6.19.3 Stanislaus River

Spawning and Egg Incubation

Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. These adult fish were observed in all habitats (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (U.S. Fish and Wildlife Service 2002).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows be moderately (≤ 20%) to substantially (≤ 38%) greater in April through June at Goodwin Dam and mouth of the Stanislaus River (Table O-261 and Table O-262). At Goodwin Dam, moderate (≤ 20%) to substantial (≤37%) increases are expected generally April through June. At the mouth, substantial (27 to 38%) increases are generally expected April through June. These results suggest flows are anticipated to have beneficial impacts on striped bass spawning.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 59°F to 68°F optimal range of water temperature for spawning, embryo incubation, and initial rearing of striped bass for April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 70 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-134. Table O-134, as described in Section O.4.19.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 59°F to 68°F optimal range of water temperature for spawning, embryo incubation, and initial rearing of striped bass, there was one month-water year type combination (6.7%) with favorable results and one month-water year type combination (6.7%) with unfavorable results at Orange Blossom Bridge (Table O-134). These results suggest that Alternative 3 would have negligible water-temperature related effects on striped bass spawning, embryo incubation, and initial rearing at Orange Blossom Bridge in the Stanislaus River.

Summary

Overall, under Alternative 3 compared to the No Action Alternative CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests flows may have beneficial impacts. The optimal water temperature range modeling estimates indicate a 6.7% month-water year type combination with beneficial and adverse results at Orange Blossom Bridge. Overall, these results suggest generally beneficial flow impacts and negligible water temperature-related impacts to striped bass spawning and egg incubation in the Stanislaus River at Goodwin Dam and the mouth under Alternative 3.

Laval and Juvenile Rearing and Emigration

Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (U.S. Fish and Wildlife Service 2002).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows be minorly (≤ 3%) to substantially (≤ 38%) greater and minorly (≤ 5%) to moderately (≤ 19%) lower at Goodwin Dam and mouth of the Stanislaus River (Table O-261 and Table O-262). At Goodwin Dam, moderate (≤ 23%) substantial (≤37%) increases are expected generally February through June and slight (6%) to moderate (≤ 19%) decreases are generally expected in January, August, September, and November. At the mouth, slight (≤ 8%) to substantial (≤38%) increases are generally expected February through July and slight (≤ 15%) decreases are generally expected January, August, September, and November. These results suggest flows may be anticipated to have beneficial and adverse impacts on striped bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 71 for Orange Blossom Bridge and Table 72 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-135. Table O-135, as described in Section O.4.19.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing there was one month-water year type combinations (1.7%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-135). There were one and six month-water year type combinations (1.7% and 10.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 3 would have negative water temperature-related impacts on juvenile striped bass rearing in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Overall, under Alternative 3 compared to the No Action Alternative CalSim 3 flow and temperature modeling had some differences. The differences determined by CalSim 3 modeling suggests flows may have beneficial impacts and adverse impacts on striped bass. The optimal water temperature range modeling estimated 1.7% (both locations) month-water year type combinations with beneficial results and 1.7% (Orange Blossom Bridge) and 10% (above the confluence with the San Joaquin River) combinations with adverse results. Overall, these results suggest there would be beneficial and adverse flow impacts on striped bass. Water temperature-related impacts on juvenile striped bass rearing would be adverse in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

O.6.19.4 San Joaquin River

Striped bass are regularly found in San Joaquin River tributaries, including in lower mainstem deep pools of the Stanislaus and Tuolumne Rivers (e.g., Anderson et al. 2007). Ainsley et al. (2013) reported that striped bass were collected at two locations between the Head of the Old River and the mouth of the Stanislaus River on the mainstem San Joaquin River in May. In the San Joaquin River outflow is balanced by tidal currents, so that embryos and larvae stay suspended in the same general area in which spawning took place. Essentially, larval bass from both rivers are most abundant where salt and fresh water meet. Thus, when they begin to feed they are concentrated in the most productive portions of the entire estuary. Larval growth and survival rates are also highest in areas of brackish water, presumably because of reduced energy costs for osmoregulation (Moyle 2002).

Potential Changes to Striped Bass from Seasonal Operations

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows be minorly (≤ 1%) greater and minorly (≤ 5%) to moderately (≤ 20%) decreases at Vernalis (Table O-263). Minor to moderate decreases are generally expected in June through December. The largest decreases occur in April, July, and August (16%, 20%, and 16%, respectively). These results suggest flows may be anticipated to have adverse effects on striped bass.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on striped bass in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 3 compared to the No Action Alternative CalSim 3 modeling suggest flows may generally have moderate adverse impacts on striped bass in April, July, and August. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.6.19.5 Bay-Delta

Striped bass use the Delta as a migratory route and for rearing and seasonal foraging. Striped bass spend the majority of their lives in salt water, returning to freshwater to spawn. Adult striped bass spend about six to nine months of the year in San Francisco and San Pablo Bays (Hassler 1988). Striped bass also use deeper areas of many of the larger channels in the Delta, in addition to large embayments such as Suisun Bay.

Spawning occurs in spring, primarily in the Sacramento River between Sacramento and Colusa and in the San Joaquin River between Antioch and Venice Island (Farley 1966). Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all striped bass eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows be minorly (≤ 4%) to substantially (≤ 42%) greater and minorly (4%) to substantially (≤ 151%) lower in the Bay-Delta (Table O-253 through Table O-255). At SWP and CVP exports, slight (15%) to substantial (69%) flow decreases throughout the year with the greatest decreases generally occurring in April and May. At the confluence of Old and Middle River in the Delta, substantial (≤151%) flow decreases year round with the greatest decreases generally occurring in April and May. At Delta Outflow, slight (≤ 8%) to substantial (≤42%) increases are expected for an average of 8 months of the year. These differences suggest flows will have adverse effects and beneficial effects on striped bass.

Potential Changes to Striped Bass from Seasonal Operations

Differences in Delta outflow between April and June due to seasonal operations under Alternative 3 compared with the No Action Alternative may have effects on striped bass annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the striped bass.

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for striped bass indicated that the overall average abundance index for Alternative 3 would be the highest when compared to the No Action Alternative across all water year types (+9% to +19%, +11% overall).

Summary

Overall, under Alternative 3 compared to the No Action Alternative CalSim 3 flow and Delta outflow modeling had some differences. The differences determined by CalSim 3 modeling suggests flows may have beneficial impacts at two Delta locations and adverse impacts at one location. Predictions from the Delta Outflow model for striped bass indicated that the overall average abundance index for Alternative 3 would be generally greater than the No Action Alternative all water year types. Overall, these results suggest adverse flow impacts on striped bass at export facilities and OMR but beneficial flow impacts at Delta Outflow.

Potential Changes to Entrainment of Striped Bass

Differences in exports under Alternative 3 compared with the No Action Alternative may have effects on striped bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for striped bass include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of striped bass under Alternative 3 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were lower all water year types, except at SWP Banks Pumping Plant on critically dry water years when loss was up to 13% greater (Tables O-136 and O-137). At the SWP Banks Pumping Plant predicted average monthly loss was up to 58% lower on above normal water years (Table O-136). At CVP Jones Pumping Plant predicted average monthly loss of striped bass was up to 85% lower on dry water years (Table O-137).

Summary

Overall, under Alternative 3 compared to the No Action Alternative salvage density modeling had some differences. The salvage density modeling predicted monthly loss under Alternative 3 are similar or greater at SWP Bank Pumping Plant and similar or lower at CVP Jones Pumping Plant all water year types. Overall, loss decreases from entrainment are anticipated most water year types under Alternative 3.

O.6.20 American Shad

O.6.20.1 Sacramento River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River. Migrating adults generally take 2 to 3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962).

Potential Changes to American Shad from Seasonal Operations

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Keswick Dam under Alternative 3 range from about 3,500 cfs for March in critically dry years to 24,000 cfs for February of wet water years (Table O-248). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Alternative 3 relative to the No Action Alternative has differences in flow that are small in these months, but flows are moderately lower (16%) for Alternative 3 in April of dry water years (Table O-248). Therefore, Alternative 3 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 319 for Butte City.

Results for the analysis are summarized in Table O-138. Table O-138, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 62°F to 75°F optimal range, there were two month-water year type combinations (13.3% of total combinations during the period) with favorable results at Butte City (Table O-138). There was one combination (6.7%) with unfavorable results at Butte City. These results suggest that there would be positive water temperature-related effects of Alternative 3 on American shad spawning and larval rearing in the Sacramento River.

Alternative 3 relative to the No Action Alternative is expected to have negligible impact on American shad spawning and larval rearing due to differences in flow below Keswick Dam in the Sacramento River. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation under Alternative 3 compared to the No Action Alternative will have a beneficial impact on American shad spawning and larval rearing in the Sacramento River. Therefore, the differences in flow and temperature under Alternative 3 compared to the No Action Alternative in the Sacramento River are expected to have some beneficial effects on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

In the Sacramento River, summer rearing habitat occurs in the main river from Colusa to the north Delta (Stevens et al. 1987). As the season progresses, juvenile shad move downstream and enter salt water primarily during September through November (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Keswick Dam under Alternative 3 range from about 4,700 cfs for October in critically dry years to 8,500 cfs for September of wet water years (Table O-248). Because American shad are anadromous fish that migrate great lengths to reach their spawning grounds, these flow levels are likely to be adequate for juvenile rearing and emigration, so no adverse impacts are expected to result. Alternative 3 relative to the No Action Alternative has differences in flow that are moderately lower (14%) for Alternative 3 in September and November of above normal water years (Table O-248). Therefore, Alternative 3 would likely have negligible flow impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F range optimal range for juvenile rearing and emigration during July through November are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 320 for Butte City.

Results for the analysis are summarized in Table O-139. Table O-139, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 63°F to 77°F optimal range, there were four month-water year type combinations (16.0% of total combinations during the period) with favorable results at Butte City (Table O-139). There was one month-water year type combination (4.0%) with unfavorable results at Butte City. These results suggest that there would be positive water temperature-related effects of Alternative 3 on American shad juvenile rearing and emigration in the Sacramento River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have negligible impact on American shad juvenile rearing and emigration due to differences in flow. Flow for rearing and emigration does not appear to be a limiting factor for American shad. Water temperatures for larval rearing and emigration under Alternative 3 compared to the No Action Alternative are suggested to have beneficial impact on American shad juvenile rearing and emigration in the lower American River. Therefore, the differences in flow and temperature for Alternative 3 compared to the No Action Alternative are expected to have some beneficial impacts on American shad juvenile rearing and emigration.

O.6.20.2 Lower American River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River. Migrating adults generally take 2 to3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962). Adult American shad migrate into the lower American River to spawn during the late spring, typically during April through early July (California Department of Fish and Wildlife 1986).

Potential Changes to American Shad from Seasonal Operations

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Nimbus Dam and H street under Alternative 3 range from about 870 cfs for April in critically dry years to 12,300 cfs for February of wet water years (Table O-259 and Table O-260). Alternative 3 relative to the No Action Alternative has differences in flow that are generally minimal in these months below Nimbus Dam with a reduction of flow (15%) in March of critically dry years, but flows are higher at H Street (37%) for Alternative 3 in April of critically dry water years (Table O-259 and Table O-260). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 3 cannot be determined to have adverse effects. Therefore, Alternative 3 would likely have negligible impact on American shad eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range for American shad spawning and larval rearing during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 97 for Hazel Avenue and Table 98 for Watt Avenue.

Results for the analysis are summarized in Table O-140. Table O-140, as described in Section O.4.20.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 62°F to 75°F optimal range for American shad spawning and larval rearing under Alternative 3, there were three and zero month-water combinations (20.0% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-140). There were zero month-water combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 3, there would be positive water temperature-related effects to American shad spawning and larval rearing in the lower American River at Hazel Avenue and Watt Avenue.

Alternative 3 relative to the No Action Alternative is expected to have minimal impact on American shad spawning and larval rearing due to differences in flow below Nimbus Dam and at H Street. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation from Hazel Avenue and Watt Avenue under Alternative 3 compared to the No Action Alternative will have a beneficial impact on American shad spawning and larval rearing in the lower American River. Therefore, the differences in flow and temperature under Alternative 3 compared to the No Action Alternative in the lower American River are expected to have some beneficial impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

American shad rearing and emigration in the lower American River is dependent on water temperatures. August through September, but before November, are optimal months for juvenile American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Nimbus Dam and H street under Alternative 3 range from about 600 cfs for October in critically dry years to 4,100 cfs for November of wet water years (Table O-259 and Table O-260). Alternative 3 relative to the No Action Alternative has differences in flow that are slightly lower (14%) for Alternative 3 below Nimbus Dam in November during critically dry years (Table O-259) and increasingly lower (31%) at H St. in November during critically dry years (Table O-260). Because American shad are anadromous fish that migrate great lengths to reach their spawning grounds, these flow levels are likely to be adequate for juvenile rearing and emigration, so no adverse effects are expected to result. Therefore, Alternative 3 would likely have negligible impacts from flow on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for American shad juvenile rearing and emigration during July through November are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 99 for Hazel Avenue and Table 100 for Watt Avenue.

Results for the analysis are summarized in Table O-141. Table O-141, as described in Section O.4.20.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 63°F to 77°F optimal range for American shad juvenile rearing and emigration under Alternative 3, there were three month-water combinations (12.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-141). There were one and zero month-water combinations (4.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 3, there would be positive water temperature-related effects to American shad juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 3 relative to the No Action Alternative is expected to have a negligible impact on American shad juvenile rearing and emigration due to differences in flow. Flow for rearing and emigration is not a limiting factor for American shad. Water temperatures for larval rearing and emigration at Hazel Avenue and Watt Avenue under Alternative 3 compared to the No Action Alternative are suggested to have beneficial impacts on American shad juvenile rearing and emigration in the lower American River. Therefore, the differences in flow and water temperature under Alternative 3 relative to the No Action Alternative are expected to have some beneficial impacts on American shad juvenile rearing and emigration.

O.6.20.3 Stanislaus River

Spawning and Larval Rearing

American shad migrate up the Stanislaus River to spawn in the late spring and support a sport fishery during that period. American shad have been observed on occasion from June through July at Lovers Leap (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). American shad were found primarily in the faster habitats and were observed in schools of 20 or more (U.S. Fish and Wildlife Service 2002).

Potential Changes to American Shad from Seasonal Operations

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Goodwin Dam and Stanislaus River mouth under Alternative 3 range from about 180 cfs for March in critically dry years to 2600 cfs for February below Goodwin Dam and at Stanislaus River Mouth of wet water years (Table O-261 & Table O-262). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these

flow levels are likely to be adequate for spawning and incubation. Alternative 3 relative to the No Action Alternative has differences in flow that are 68% higher for Alternative 3 in February below Goodwin Dam and 51% higher in March at the Stanislaus River Mouth for dry water years (Table O-261 & Table O-262) This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 3 cannot be determined to have adverse effects. Therefore, Alternative 3 would likely have negligible impact on American shad eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range for American shad spawning and larval rearing during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 73 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-142. Table O-142, as described in Section O.4.20.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 59°F to 68°F 62°F to 75°F optimal range for American shad spawning and larval rearing, there were zero month-water year type combinations (0.0%) with favorable and zero month-water year type combinations with unfavorable results at Orange Blossom Bridge (Table O-142).

These results suggest that Alternative 3 would have negligible water-temperature related effects on American shad spawning and larval rearing at Orange Blossom Bridge in the Stanislaus River.

Summary

Alternative 3 relative to the No Action Alternative is expected to have negligible impact on American shad spawning and larval rearing due to differences in flow. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation at Orange Bridge Dam and above the confluence under Alternative 3 compared to the No Action Alternative will have negligible water-temperature related impacts on American shad spawning and larval rearing at Orange Blossom Bridge in the Stanislaus River. Therefore, the differences in flow and temperature for Alternative 3 compared to the No Action Alternative in the lower American River are expected to have some negligible impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

American shad rearing and emigration in the Stanislaus River is dependent on water temperatures. From Orange Blossom Bridge to just above the confluence, juvenile rearing and emigration generally occur in July for American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Goodwin Dam and Stanislaus River Mouth under Alternative 3 range from about 160 cfs for September at Stanislaus River Mouth in critically dry years to 800 cfs below Goodwin Dam in October during wet water years (Table O-261 & Table O-262). Alternative 3 relative to the No Action Alternative has differences in flow that are unchanged below Goodwin Dam and 10% higher at Stanislaus River Mouth in September during critically dry years (Table O-261 & Table O-262). With no change below Goodwin Dam and a slight increase in flows at Stanislaus River Mouth, American Shad should see no adverse affects from Alternative 3. Therefore, Alternative 3 would likely have negligible flow impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for American shad juvenile rearing and emigration during July through November are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 74 for Orange Blossom Bridge and Table 75 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-143. Table O-143, as described in Section O.4.20.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 63°F to 77°F optimal range for American shad juvenile rearing and emigration there were zero and two month-water year type combinations (0.0% and 8.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-143). There were zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River.

These results suggest that Alternative 3 would have negligible water temperature-related effects on American shad juvenile rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Alternative 3 relative to the No Action Alternative is expected to have negligible impacts on American shad juvenile rearing and emigration due to differences in flow. Flow for rearing and emigration is not a limiting factor for American shad. Water temperatures for juvenile rearing and emigration at Orange Blossom Bridge and above the confluence under Alternative 3 compared to the No Action Alternative are suggested to have negligible water temperature-related impacts on American shad juvenile rearing and emigration in the Stanislaus River. Therefore, the differences in flow and temperature for Alternative 3 compared to the No Action Alternative are expected to have negligible impacts on American shad juvenile rearing and emigration.

O.6.20.4 San Joaquin River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas. Migrating adults generally take 2 to3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962).

Little is known about American shad populations inhabiting the San Joaquin River. American shad may spawn in the San Joaquin River system, but their abundance is unknown.

Potential Changes to American Shad from Seasonal Operations

During the February to April adult American shad migration into the Delta, CalSim 3 estimates of mean monthly flows in the San Joaquin River at Vernalis under Alternative 3 range from about 1,800 cfs for March critically dry years to 13,000 cfs for February (Table O-263). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Alternative 3 relative to the No Action Alternative has differences in flow that are slightly lower (~10%) for Alternative 3 in March and April of critically dry water years (Table O-263) This decrease in flows could result in a reduction of spawning habitat for American shad but Alternative 3 cannot be determined to have adverse effects. Therefore, Alternative 3 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on American shad spawning and larval rearing in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the American shad spawning and larval rearing period (Figure O-15).

<u>Summary</u>

There may be negligible impacts from seasonal operations on American shad spawning and larval rearing based on analyses of simulated flows under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are also like to have negligible impacts on American shad juvenile rearing and non-spawning adult. Under Alternative 3, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the American shad spawning and larval rearing period.

Juvenile Rearing and Emigration

American shad juvenile rearing and emigration is dependent on water temperatures. Generally, juvenile rearing and emigration generally occur in July for American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

During the September to November juvenile American shad emigration back into the Delta, CalSim 3 estimates of mean monthly flows in the San Joaquin River at Vernalis under

Alternative 3 range from about 600 cfs for September in critically dry years to 2,800 cfs for November in the San Joaquin River at Vernalis of wet water years (Table O-263) Alternative 3 relative to the No Action Alternative has differences in flow that are slightly lower (12%) for Alternative 3 in September in the San Joaquin River at Vernalis during critically dry years (Table O-263). With these flows, American shad may lose some rearing habitat but may not be affected by Alternative 3. Therefore, Alternative 3 would likely have negligible impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on American shad in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile rearing and emigration period (Figure O-15).

Summary

There may be negligible impacts from seasonal operations on American shad juvenile rearing and non-spawning adults based on analyses of simulated flows under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are unlikely to have an impact on American shad juvenile rearing and non-spawning adult. Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are also likely to have a negligible impact on American shad in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile rearing and emigration period.

O.6.20.5 Bay-Delta

American shad spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento, Feather, American, and Yuba Rivers. Some spawning also takes place in the lower San Joaquin, Mokelumne, and Stanislaus Rivers (U.S. Fish and Wildlife Service 1995). The spawning migration may begin as early as February, but most adults migrate into the Delta in March and early April (Skinner 1962). Migrating adults generally take 2 to 3 months to pass through the Sacramento–San Joaquin estuary (Painter et al. 1979).

American shad rearing and emigration in the Bay-Delta is dependent on water temperatures. August through September, but before November, are optimal months for juvenile American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

Differences in Delta outflow between February and June due to seasonal operations under Alternative 3 compared with the No Action Alternative may have impacts on American shad annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the American shad.

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for American shad indicate that Alternative 3 would lead to higher mean American shad abundance compared to the No Action Alternative across all water year types (+7% in wet years to +13% in critically dry years, and +9% overall).

Summary

There may be beneficial impacts from seasonal operations on American shad abundance based on analyses of simulated flows under Alternative 3 in comparison to the No Action Alternative. American shad abundance index would increase across all water year types in the Bay-Delta based on the Delta Outflow model.

Potential Changes to Entrainment of American Shad

Salvage Density

Predictions from the salvage density model for American shad include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative. Predicted average monthly loss of American shad under Alternative 3 compared to the No Action Alternative at the SWP Banks Pumping Plant decreased all water year types, except for critically dry water years when loss was similar and CVP Jones Pumping Plant decreased all water year types (Tables O-144 and O-145). At the SWP Banks Pumping Plant predicted average monthly loss was up to 58% lower on above normal water year types (Table O-144). At CVP Jones Pumping Plant predicted average monthly loss was up to 78% lower on above normal water year types (Table O-145).

Summary

There may be beneficial impacts on American shad entrainment based on analyses of simulated exports under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, entrainment decreased at both Jones Pumping Plant and Banks Pumping Plant during all water year types.

O.6.21 Threadfin Shad

O.6.21.1 Sacramento River

Spawning for threadfin shad takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Threadfin shad are occasionally caught at the Red Bluff Diversion Dam rotary screw trap in the Sacramento River, and occur year-round (Voss 2024).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 3 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal spawning range during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 321 for Butte City.

Results for the analysis are summarized in Table O-146. Table O-146, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 63°F to 77°F optimal range, there were four month-water year type combinations (16.0% of total combinations during the period) with favorable results at Butte City (Table O-146). There were three month-water year type combinations (12.0%) with unfavorable results at Butte City. These results suggest that there would be both positive and negative water temperature-related impacts from Alternative 3 on threadfin shad spawning in the Sacramento River.

Summary

There may be beneficial and adverse impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are likely to have negligible impacts on threadfin shad. Temperature analysis suggests both beneficial and adverse impacts of Alternative 3 on threadfin shad spawning in the Sacramento River.

O.6.21.2 Lower American River

Spawning for threadfin shad takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. Threadfin shad are occasionally captured as part of the non-salmonid bi-catch in the rotary screw traps in the lower American River (Pacific States Marine Fisheries Commission 2014).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 3 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for threadfin shad adult spawning during April through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 101 for Hazel Avenue and Table 102 for Watt Avenue.

Results for the analysis are summarized in Table O-147. Table O-147, as described in Section O.4.21.2 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 63°F to 77°F optimal range for threadfin shad adult spawning under Alternative 3, there were two and one month-water combinations (8.0% and 4.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-147). There were one and zero month-water combinations (4.0% and 0.0%, respectively) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 3, there would be negligible water temperature-related effects to threadfin shad adult spawning in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are likely to have negligible impacts on threadfin shad. Temperature analysis suggests negligible impacts of Alternative 3 on threadfin shad spawning in the lower American River.

O.6.21.3 Stanislaus River

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and

abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Threadfin shad are occasionally captured in the Caswell RST in the lower Stanislaus River (Bradbury and Hickey 2019).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 3 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for threadfin shad adult spawning during April through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 76 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-148. Table O-148, as described in Section O.4.21.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 63°F to 77°F optimal range for threadfin shad adult spawning, there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge (Table O-148).

These results suggest that Alternative 3 would have negligible water-temperature related impacts on threadfin shad spawning in the Stanislaus River at Orange Blossom Bridge.

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are likely to have a negligible impact on threadfin shad. Temperature analysis also suggests negligible impacts from Alternative 3 on threadfin shad spawning in the Stanislaus River.

O.6.21.4 San Joaquin River

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Juveniles can form dense schools and while they are typically abundant in freshwater, they may also be found in varying salinities throughout the estuary. Threadfin shad are fast-growing but short-lived, with an average lifespan of two years.

Potential Changes to Threadfin Shad from Seasonal Operations

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 3 are likely adequate for threadfin shad.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on threadfin shad in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, changes in flows are likely to have a negligible impact on threadfin shad. Under Alternative 3, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the year in the San Joaquin River at Vernalis.

O.6.21.5 Bay-Delta

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004).

Potential Changes to Threadfin Shad from Seasonal Operations

There is no strong evidence that flow influences threadfin shad abundance. While Dege and Brown (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 3 are likely adequate for threadfin shad.

Summary

There may be negligible impacts from seasonal operations on threadfin shad under Alternative 3 in comparison to the No Action Alternative.

Potential Changes to Entrainment of Threadfin Shad

Differences in exports under Alternative 3 compared with the No Action Alternative may have effects on threadfin shad entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for threadfin shad include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of threadfin shad under Alternative 3 compared to the No Action Alternative at the SWP Banks Pumping Plant decreased all water year types, except for critically dry water years when loss was similar and CVP Jones Pumping Plant decreased all water year types (Tables O-149 and O-150). At the SWP Banks Pumping Plant predicted average monthly loss was up to 58% lower on above normal water year types (Table O-149). At CVP Jones Pumping Plant predicted average monthly loss was up to 78% lower on above normal water year types (Table O-150).

Summary

There may be beneficial changes to entrainment on threadfin shad juvenile rearing and non-spawning adults based on analyses of simulated exports under Alternative 3 in comparison to the No Action Alternative. Under Alternative 3, entrainment decreased at Banks across all water year types except for the critically dry water year type, while entrainment at Jones decreased across all water year types.

O.6.22 Black Basses

O.6.22.1 Three Micropterus spp.

Three *Micropterus* spp. constitute the group of black basses in California, and include largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species). All three species are introduced but have recreational value in California.

Largemouth Bass

Largemouth bass first spawn during their second or third spring at about 7 inches in length. Spawning is limited to freshwater (Moyle 2002). The males begin building nests when the water temperature reaches about 60°F (15.6°C). Spawning takes place from April through June, at temperatures up to 75°F (23.9°C).

Smallmouth Bass

Smallmouth bass reach maturity in their third or fourth spring, at which point they move into shallower water. Spawning begins in May and can continue into June or July (Moyle 2002). Spawning has been observed at temperatures ranging from 13°C to 26°C (55.4°F to 78.8°F), with optimal water temperatures ranging from 16°C to 18°C (60.8°F to 64.4°F) (Wang et al. 2010).

Spotted Bass

Maturity is reached in the second or third year and spawning occurs in freshwater when temperatures reach 15°C to 18°C (59°F to 64.4°F), continuing until temperatures reach 22°C to 23°C (71.6°F to 73.4°F) in early June. Males move to shallow water in March and early April, where they construct nests 40 to 80 cm (31.5 inches) in diameter, generally in shallow areas less than or equal to 6 m deep (University of California, Agriculture and Natural Resources 2019b; Wang et al. 2010).

O.6.22.2 Sacramento River

Spawning

Spawning occurs in freshwater for all three taxa. This means all spawning occurs upstream of the brackish estuary. See details in Section O.4.22.1 above for spawning timing for each species.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

<u>CalSim 3 Flow Analysis</u>

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows at Keswick Dam, Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤5%) increase or decrease is estimated March through April and slight increase or decrease May through July. In May flows would be generally higher (≥ 6%), lower in June (≥ 10%), and lower July (≥ 6%). These results suggest slightly adverse effects on largemouth, smallmouth, and spotted bass habitat under Alternative 3 comparted to the No Action Alternative (Table O-248 through Table O-251).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 323 for Butte City. Full results of the analysis assessing the percent of months with water temperature outside the 55°F to 70°F optimal range for smallmouth bass spawning during May through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 325 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 331 for Butte City.

Results for the three analyses are summarized in Table O-151. Table O-151, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-151). For the 55°F to 70°F optimal range for smallmouth bass spawning, there were no month-water year type combinations (0%) with favorable results at Hamilton City. There was one combination (6.7%) with unfavorable results. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Butte City. These results suggest that there would be negligible water temperature-related effects of Alternative 3 on black bass spawning in the Sacramento River.

Summary

Overall, Alternative 3 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests slight adverse impacts on largemouth, smallmouth, and spotted bass spawning habitat extent may be expected. The optimal water temperature range modeling estimates indicate neither beneficial nor adverse impacts on largemouth and spotted bass under Alternative 3 compared to the No Action Alternative in the Sacramento River. The optimal water temperature range modeling estimates indicate 6.7% adverse combinations at Hamilton City for smallmouth bass in the Sacramento River. Overall, these results suggest that there would be slight adverse impact from flow for largemouth, smallmouth, and spotted bass spawning habitat; negligible water temperature-related impacts are anticipated on largemouth and spotted bass, and slight adverse smallmouth bass spawning and egg incubation in the Sacramento River under Alternative 3.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters and may be found from the tributaries of the Sacramento to the brackish estuary. As all three taxa require large quantities of food, they are likely to be more concentrated in areas with plentiful food and instream cover.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows at Keswick Dam, Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (<5%) increase and/or decrease is estimated most months except May (higher), June (lower), July (lower), August (higher, Wilkins Slough and Hamilton City), September (lower, Wilkins Slough), and December (higher, Keswick Dam); this suggest effects on largemouth, smallmouth, and spotted bass habitat will generally remain similar to the No Action Alternative (Table O-248 through Table O-251).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 324 at Butte City. Full results of the analysis assessing the percent of months with water temperature above the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 327 for the Sacramento River at Hamilton. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for non-spawning adult smallmouth bass growth year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 320 for the Sacramento River at Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 332 for the Sacramento River at Butte City.

Results for the four analyses are summarized in Table O-152. Table O-152, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-152). For the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass, there were two month-water year type combinations (13.3%) with both favorable and unfavorable results at Hamilton City. For the 77°F to 80°F optimal range for non-spawning adult smallmouth bass growth, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Hamilton City. For the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Butte City. These results suggest that there would be positive and negative effects of Alternative 3 on black bass non-spawning adults in the Sacramento River.

Summary

Overall, Alternative 3 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will generally remain similar with some slight adverse impacts. The optimal summer water temperature range modeling estimates indicate neither beneficial nor adverse conditions for largemouth and spotted bass compared to the No Action Alternative at Butte and Hamilton cities in the Sacramento River. The optimal summer water temperature range modeling estimates indicate 13.3% adverse and beneficial month-water year type combinations for smallmouth bass in the lower end of optimal range at Hamilton City. Overall, these results suggest there would be minor to slight adverse impact from flow for largemouth, smallmouth, and spotted bass; negligible water temperature-related impacts on largemouth, smallmouth, and spotted bass adults are expected in the Sacramento River under Alternative 3.

O.6.22.3 Lower American River

Spawning

Spawning for all three taxa occurs in cooler, shallow waters with flow. See details in Section O.4.22.1 above for spawning timing for each species.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam and in the lower American River at H Street indicate that minor (≤ 6%) to substantial (≤ 29%) increases or decreases are estimated March through June (Tables O-258 through O-260). Below Nimbus Dam, slight (12%, July) moderate (27%, June) decreases and minor (March) and moderate (16%, April) increases are expected. At H street, minor (March) and moderate (16%, April) increases and slight (13%, July) and moderate (29%, June) increases are expected. These results suggest adverse effects on largemouth, smallmouth, and spotted bass may be below Nimbus Dam and H street generally in June and July and beneficial effects in March and April.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 105 for Hazel Avenue and Table 106 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 55°F to 70°F optimal range for smallmouth bass spawning during May through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 109 for Hazel Avenue and Table 110 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 115 for Hazel Avenue and Table 116 for Watt Avenue.

Results for the three analyses are summarized in Table O-153. Table O-153, as described in Section O.4.22.2,reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were two and zero month-water year type combinations (13.3% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-153). There were one and zero month-water year type combinations (6.7% and 0%, respectively) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively. For the 55°F to 70°F optimal range for smallmouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at Hazel Avenue and Watt Avenue. There were 0 and 4 month-water year type combinations (0.0% and 26.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were four and zero month-water year type combinations (26.7% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and five month-water year type combinations (0.0% and 33.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be similar positive and negative effects of Alternative 3 on black bass spawning in the lower American River.

Summary

Overall, Alternative 3 compared to the No Action Alternative CalSim 3 flow modeling and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests a mix of beneficial (March and April) and adverse (June and July) flow impacts largemouth, smallmouth, and spotted spawning habitat. The optimal water temperature range modeling estimates indicate two (13.3%, Hazel Avenue) beneficial and 1 (6.7%, Watt Avenue) adverse month-water year type beneficial combination for largemouth bass. The optimal water temperature range modeling estimates indicate four (26.7%, Watt Avenue) adverse combinations for smallmouth bass. The optimal water temperature range modeling estimates indicate one (6.7%, Hazel Avenue) beneficial and five (33.3%, Watt Avenue) adverse combinations for spotted bass. Overall, these results suggest that there would be generally beneficial (March and April) and adverse (June and July) flow impacts on largemouth, smallmouth, and spotted spawning habitat; water temperature-related impacts would be slightly beneficial on largemouth bass spawning, moderately adverse on smallmouth, and slightly adverse on spotted bass in the lower American River under Alternative 3.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters. However, they require large quantities of food; they are likely to remain in slower moving waters of the stream or move vertically within the lake to accommodate preferences.

Potential Changes to Black Basses from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam, and H Street indicate that minor (≤ 5%) increase and/or decrease is estimated nearly half of the months (Table O-259 and Table O-260). Below Nimbus Dam, slight (12%, June) moderate (27%, June) decreases are expected an average three months out of year; slight (≤ 10%, March and August) and moderate (16%, April) increases are expected. At H street, slight (≤ 11%, March and August) and moderate (16%, April) increases are expected an average three months out of year; slight (13%, June) and moderate (29%, June) increases are expected. These results suggest largemouth, smallmouth, and spotted bass habitat will be adversely affected below Nimbus Dam and have a beneficial effect at H street generally in June and July.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for growth for largemouth bass during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 107 for Hazel Avenue and Table 108 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 111 for Hazel Avenue and Table 112 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for growth in smallmouth bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 113 for Hazel Avenue and 114 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 75°F to 87°F preferred summer-time range for spotted bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 117 for Hazel Avenue and Table 118 for Watt Avenue.

Results for the four analyses are summarized in Table O-154. Table O-154, as described in Section O.4.22.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue (Table O-154). There were also zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there were zero and one month-water year type combinations (0.0% and 20.0%) with favorable results at both Hazel Avenue and Watt Avenue. There was one month-water year type combinations (6.7%) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were zero month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75°F to 87°F preferred

summer-time range for spotted bass, there were zero month-water year type combinations (0.0% with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0%,) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that there would be positive effects of Alternative 3 on black bass non-spawning adults in the lower American River.

Summary

Overall, Alternative 3 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will remain similar with some beneficial and adverse impacts. The optimal water temperature range modeling estimates indicate largemouth bass are neither beneficial nor adverse at the lower American River. The optimal water temperature range modeling estimates indicate one (6.7%, Hazel Avenue and Watt Avenue) adverse month-water year type combinations and three (20.0%, Hazel Avenue) beneficial combinations at the 66°F water temperature lower end summer-time range of smallmouth bass. The optimal water temperature range modeling estimates indicate one (6.7%, Watt Avenue) beneficial combination for spotted bass. Overall, these results suggest there would be generally slight beneficial flow impacts on largemouth, smallmouth, and spotted bass; water temperature-related impacts on non-spawning adult largemouth bass would be negligible, and on non-spawning adult smallmouth and spotted bass would be slightly beneficial in the lower American River.

O.6.22.4 Stanislaus River

Spawning

Spawning for all three taxa occurs in cooler, shallow waters with flow. See details in Section O.4.22.1 above for spawning timing for each species. The Stanislaus River supports spawning for largemouth bass and spotted bass.

Potential Changes to Largemouth and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows be slightly (≤ 8%) to substantially (≤ 38%) greater and minorly (≤ 5%) lower at Goodwin Dam and mouth of the Stanislaus River (Table O-261 and Table O-262). At Goodwin Dam, moderate (≤ 20%) to substantial (≤37%) increases are expected generally March through June and minor decrease is generally expected July. At the mouth, slight (≤ 8%) to substantial (≤38%) increases are generally expected March through July and slight (≤ 15%). These results suggest flows may be anticipated to have beneficial effects on largemouth, smallmouth, and spotted bass spawning.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 78 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April

through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 82 for Orange Blossom Bridge.

Results for the two analyses are summarized in Table O-155. Table O-155, as described in Section O.4.22.4,reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results and one month-water year type combinations (6.7%) with unfavorable results at Orange Blossom Bridge (Table O-155). For the 58.1°F to 73.4°F observed range for spotted bass spawning, there was one month-water type combination (6.7%) with favorable and unfavorable results at Orange Blossom Bridge.

These results suggest that there would be negligible negative effects of Alternative 3 on spawning black basses spawning in the Stanislaus River.

Summary

Overall, Alternative 3 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The fluctuations determined by CalSim 3 modeling suggests projected averaged flows may have generally beneficial impacts. The optimal water temperature range modeling estimates indicate one (6.7%) month-water year type combinations with adverse conditions for largemouth bass. The optimal water temperature range modeling estimates indicate one (6.7%) month-water year type combinations with adverse and beneficial conditions for spotted bass. Overall, these results suggest generally beneficial flow impacts on largemouth, smallmouth, and spotted bass; water temperature-related impacts on largemouth bass spawning are slightly negative and negligible on spotted bass under Alternative 3.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters. However, they require large quantities of food; they are likely to remain in slower moving waters of the stream or move vertically within the reservoirs to accommodate preferences.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows be minorly (≤ 3%) to substantially (≤ 38%) greater and minorly (≤ 5%) to moderately (≤ 19%) lower at Goodwin Dam and mouth of the Stanislaus River (Table O-261 and Table O-262). At Goodwin Dam, moderate (≤ 23%) substantial (≤37%) increases are expected generally February through June and slight (6%) to moderate (≤ 19%) decreases are generally expected in January, August, September, and November. At the mouth, slight (≤ 8%) to substantial (≤38%) increases are generally expected February through July and slight (≤ 15%) decreases are generally expected January, August, September, and November. These results suggest flows may be anticipated to have beneficial effects and adverse effects on largemouth, smallmouth, and spotted bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for growth for largemouth bass during year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 79 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass during June through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 80 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for growth in smallmouth bass during year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 81 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 75°F to 87°F preferred summer-time range for spotted bass during June through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 83 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-156. Table O-156, as described in Section O.4.22.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 3 for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0% with favorable and unfavorable results at Orange Blossom Road (Table O-156). For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there were zero month-water year type combinations (0.0% with favorable and unfavorable results at Orange Blossom Road. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were zero month-water year type combinations (0.0% with favorable and unfavorable results at Orange Blossom Road For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero month-water year type combinations (0.0% with favorable and unfavorable results at Orange Blossom Road.

These results suggest that there would be negligible effects of Alternative 3 on black bass non-spawning adults in the Stanislaus River at Orange Blossom Bridge.

Summary

Overall, Alternative 3 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests flows may have generally beneficial impacts on largemouth, smallmouth, and spotted bass. The optimal water temperature range modeling estimates were neither beneficial nor adverse for largemouth, smallmouth, and spotted bass. Overall, these results suggest generally beneficial flow and similar water temperature-related impacts on non-spawning largemouth, smallmouth, and spotted bass in the Stanislaus River under Alternative 3 compared to the No Action Alternative.

O.6.22.5 San Joaquin River

Spawning occurs in freshwater for all three taxa. This means all spawning occurs upstream of the brackish estuary. Non-spawning adults are generally more tolerant of various water quality parameters and may be found from the tributaries of the San Joaquin to the brackish estuary. As all three taxa require large quantities of food, they are more likely to be concentrated in areas with plentiful food and instream cover.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows be minorly (≤ 1%) greater and minorly (≤ 5%) to moderately (≤ 20%) decreases at Vernalis (Table O-263). Minor to moderate decreases are generally expected in June through December. The largest decreases occur in April, July, and August (16%, 20%, and 16%, respectively). These results suggest flows may be anticipated to have adverse effects on largemouth, smallmouth, and spotted bass.

Changes in water temperature from seasonal operations under Alternative 3 compared to the No Action Alternative are likely to have a negligible impact on black basses in the San Joaquin River. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 3 compared to the No Action Alternative CalSim 3 results differ. There are generally adverse impacts on largemouth, smallmouth, and spotted bass anticipated under Alternative 3 compared to the No Action Alternative. Under Alternative 3, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.6.22.6 Bay-Delta

Non-spawning adults are present year-round predominantly in the brackish water interface where food and is abundant. Larvae and Juveniles are likely to remain upstream of the brackish water interface, where plant beds and slower waters occur.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 3 compared to the No Action Alternative CalSim 3 mean monthly flows be minorly (≤ 4%) to substantially (≤ 42%) greater and minorly (4%) to substantially (≤ 151%) lower in the Bay-Delta (Table O-253 through Table O-255). At SWP and CVP exports, slight (15%) to substantial (69%) flow decreases throughout the year with the greatest decreases generally occurring in April and May. At the confluence of Old and Middle River in the Delta, substantial (≤151%) flow decreases year-round with the greatest decreases generally occurring in April and May. At Delta Outflow, slight (≤ 8%) to substantial (≤42%) increases are expected for an average of 8 months of the year. These differences suggest flows will have adverse effects and beneficial effects on largemouth, smallmouth, and spotted bass.

Summary

Overall, Alternative 3 compared to the No Action Alternative CalSim 3 flow modeling results had some differences. The differences determined by CalSim 3 modeling suggests flows may have beneficial impacts at two Delta locations and generally adverse impacts one location for largemouth, smallmouth, and spotted bass.

Potential Changes to Entrainment of Largemouth Bass

Differences in exports under Alternative 3 compared with the No Action Alternative may have effects on largemouth bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for largemouth bass include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of largemouth bass under Alternative 3 compared to the No Action Alternative at the SWP Banks Pumping Plant and CVP Jones Pumping Plant were lower all water year types, except at SWP Banks Pumping Plant on critically dry water years when loss was up to 214% greater (Tables O-157 and O-158). At the SWP Banks Pumping Plant predicted average monthly loss was up to 59% lower on above normal water years (Table O-157). At CVP Jones Pumping Plant predicted average monthly loss of largemouth bass was up to 85% lower on dry water years (Table O-158).

Potential Changes to Entrainment of Smallmouth Bass

Salvage Density

Predictions from the salvage density model for smallmouth bass include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of smallmouth bass of Alternative 3 compared to the No Action Alternative at SWP Banks Pumping Plant would decrease or increase all other water year types, except critically dry water year types when no fish are expected; at CVP Jones Pumping Plant loss would decrease on below normal and critically dry water year types, all other water year types have no anticipated loss (Tables O-159 and O-160). At the SWP Banks Pumping Plant predicted average monthly loss decreased up to 49% and 21% in December through February of below normal and dry water year types, respectively; loss would increase up to 12% in October and March of dry water years and 7% October of below normal water years (Table O-159). At the CVP Jones Pumping Plant predicted average monthly loss increased up to 64% and 55% January through March and May of below normal water years and February of critically dry water years, respectively (Table O-160). Historical loss of smallmouth bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Potential Changes to Entrainment of Spotted Bass

Differences in exports under Alternative 3 compared with the No Action Alternative may have effects on spotted bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for spotted bass include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of spotted bass of Alternative 3 compared to the No Action Alternative at SWP Banks Pumping Plant decreased below normal water years and no fish are expected all other water year types; at CVP Jones Pumping Plant loss decreased all water year types, except wet water years when it would be similar (Table O-161 and Table O-162). At the SWP Banks Pumping Plant predicted average monthly loss decreased up to 11% in March of below normal water years (Table O-161). At the CVP Jones Pumping Plant predicted average monthly loss decreased between 6% to 68% in November, December, and February of wet water years and in January and August of critically dry water years (Table O-162). Historical loss of spotted bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Summary

Overall, Alternative 3 compared to the No Action Alternative salvage density modeling results had some differences. The salvage density modeling predicted monthly loss under Alternative 3 are generally slightly to largely lower for largemouth bass for nearly all water year types; a few exceptions at SWP Banks Pumping Plant where slight loss increases are expected compared to the No Action Alternative. The salvage density modeling predicted monthly loss under Alternative 3 are generally slightly to largely lower for smallmouth bass for nearly all water year types; a few exceptions at SWP Banks Pumping Plant where slight loss increases are expected compared to the No Action Alternative. The salvage density modeling predicted monthly loss under Alternative 3 are generally slightly to largely lower for spotted bass for nearly all water year types. Overall, loss decreases at CVP Jones Pumping Plant and slight loss increases at SWP Banks Pumping Plant from entrainment of largemouth and smallmouth bass under Alternative 3 are expected; spotted bass loss decreases at SWP and CVP delta facilities from entrainment under Alternative 3.

O.6.23 Starry Flounder

O.6.23.1 Bay-Delta

Adult starry flounder primarily inhabit coastal marine waters (Orcutt 1950; Haertel and Osterberg 1967; Bottom et al. 1984; Hieb and Baxter 1993). Distribution of age-0 juveniles within the San Francisco Estuary and Delta is primarily in Suisun Bay and San Pablo Bay, with lower abundance in the west Delta (Baxter et al. 1999). Starry flounder older than age 1 (age-1+ fish) occur principally in San Pablo Bay, Suisun Bay, and Central Bay (Baxter et al. 1999).

Starry flounder can tolerate a wide range of salinities. In the Sacramento and San Joaquin Rivers, starry flounder have been observed in salinities as low as 0.02–0.06 ppt (i.e., essentially fresh water) (Orcutt 1950). Age-0 and age-1+ starry flounder are a common species in estuarine habitats along the West Coast (see Orcutt 1950; Pearson 1989; Emmett et al. 1991; Baxter et al. 1999; Kimmerer 2002b).

Spawning occurs primarily during the winter months of December and January (Orcutt 1950). By age-2 many starry flounder are nearing reproductive maturity and have migrated to ocean habitats adjacent to their natal estuaries. Adults may move seasonally into shallow coastal waters to spawn, perhaps in proximity to estuaries to take advantage of estuarine circulation which would advect fertilized eggs near the bottom into nursery areas.

Potential Changes to Starry Flounder from Seasonal Operations

Differences in Delta outflow between March and June due to seasonal operations under Alternative 3 compared with the No Action Alternative may have effects on starry flounder annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the starry flounder.

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for starry flounder indicated that the overall average abundance index for Alternative 3 would be the highest (15% higher than the No Action Alternative). Mean starry flounder abundance across all water year types are higher under Alternative 3 (from +12% in wet years to +28% in critically dry years).

Summary

Alternative 3 relative to the No Action Alternative is expected to have possible beneficial impacts on species abundance for the starry flounder across all water year types.

Potential Changes to Entrainment of Starry Flounder

Differences in exports under Alternative 3 compared with the No Action Alternative may have effects on starry flounder entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for starry flounder include mean monthly total exports. Table O-253 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 3 and the No Action Alternative.

Predicted average monthly loss of starry flounder under Alternative 3 compared to the No Action Alternative at the SWP Banks Pumping Plant decreased in most water year types, except for dry water years when loss was similar and critically dry water years was increased. CVP Jones Pumping Plant has a decreased salvage loss during all water year types (Table O-163 and Table O-164). At the SWP Banks Pumping Plant predicted average monthly loss was up to 46% lower in December through July of wet normal water year and 38% greater in October of critically dry

water years (Table O-163). At CVP Jones Pumping Plant predicted average monthly loss decrease ranged from 53% in June and September of critically dry water years and May and November of below normal water years to 77% in June through October of above normal water years (Table O-164). Historical loss of starry flounder at both facilities is infrequent, and this is a driver of low values of predicted loss.

Summary

Differences in exports between Alternative 3 and the No Action Alternative are expected to have possibly substantial beneficial impacts on starry flounder entrainment at Delta Fish Collection Facilities. The predicted average monthly loss of starry flounder at the SWP Banks pumping plant decreased in wetter years, was similar in drier years, and slightly increased in critically dry years. At the CVP Jones pumping plant, average monthly loss was greatly decreased across all seasons and water year types.

O.6.24 Coastal Pelagic Species

O.6.24.1 Potential Changes to Northern Anchovy and Pacific Herring from Seasonal Operations

Northern anchovy and Pacific herring could be subject to operational effects of the Proposed Action as it pertains to Delta outflow and its effect on the salinity field. However, the effects on salinity would be small relative to the salinity tolerance of Coastal Pelagic Species EFH such as Northern Anchovy (Baxter et al. 1999). Kimmerer et al. (2009) showed for Northern Anchovy that neither indices of habitat extent nor indices of abundance were related to X2, an index of Delta outflow and its effects.

Kimmerer (2009) found Pacific herring abundance indices were not associated with flow. However, Pacific herring do utilize the San Francisco Bay Estuary as spawning and rearing habitat (Pak et al. 2023, Grimaldo et al. 2020, Watters et al. 2004). Grimaldo et al. (2020) found Pacific herring larvae presence and abundance was lower in landward regions (e.g. Suisun Bay) during a high outflow year, likely due to either increased advection from high flows or reduced net landward movement via gravitational circulation. Juvenile herring abundance in Suisun Bay in the spring is associated with saltier conditions that allow their range to expand landward (Pak et al. 2023).

O.6.24.2 Potential Changes to Entrainment of Northern Anchovy and Pacific Herring

There are no expected impacts to entrainment of Northern anchovy due to operations since the distribution in the San Francisco Estuary has shifted towards higher salinities (> 20) since the introduction of the invasive clam, *Potamocorbula amurensis* (Kimmerer 2006). Impacts to entrainment of Pacific herring are potentially adverse in drier water year types depending on severity but are likely to be extremely rare. Historical salvage of Pacific herring has only occurred a few times since 2000, primarily in 2014, a critically dry year (during the months of March and April), fish were also salvaged in 2019 and 2020 in much lower numbers (CDFW 2024c).

O.6.25 Southern Oregon/Northern California Coast Coho Salmon ESU

O.6.25.1 Trinity River

Spawning and Egg/Alevin Incubation

Most coho salmon spawning in the mainstem Trinity River occurs in November and December between Lewiston Dam and the North Fork Trinity River (Section O.1.2.5.1, *Coho salmon, Southern Oregon/Northern California Coast ESU*). Coho salmon eggs and alevins in the Trinity and Klamath River Basins may be present in the gravel from November to mid-May (Leidy and Leidy 1984), so effects of flow and water temperature on coho salmon eggs and alevins may occur during this period.

Potential Changes to Coho Salmon from Seasonal Operations

Under Alternative 3, modeled monthly average flows in the Trinity River below Lewiston Dam in December of wet and below normal water years, in January of wet water years, and in February of wet and above normal water years would be at least 5% greater than the No Action Alternative (Table O_Trin_Alt3). Monthly average flows in March of below normal water years and April of wet water years would be at least 5% less than the No Action Alternative. These changes would have variable effects on the availability and suitability of spawning and egg/alevin incubation habitat for coho salmon. From May through November, modeled monthly average flows under Alternative 3 would be the same as the No Action Alternative or would not differ substantially (by more than 5%) in any month or water year type.

In December when coho salmon are spawning and eggs/alevins may be incubating in the Trinity River, modeled monthly average flow would increase in wet water years from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 and in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 (Table O-246). In January when coho salmon eggs/alevins may be incubating, monthly average flow would increase in wet water years from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3. In February when coho salmon eggs/alevins may be incubating, monthly average flow would increase in wet water years from 1,843 cfs under the No Action Alternative to 1,962 cfs under Alternative 3 and in above normal water years from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3.

The modeled December flow increases may increase WUA for coho salmon spawning in the reach from Dutch Creek to North Fork Trinity River but would reduce WUA for coho salmon spawners in downstream reaches (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The effect on spawning suitability in the reach from Lewiston Dam to Dutch Creek has not been quantified for flows above 800 cfs (U.S. Fish and Wildlife Service and Hoopa Valley Tribe 1999) and, as in other reaches, is likely to vary spatially with channel confinement and incision (Goodman et al. 2018). In locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships. Although WUA for egg/alevin incubation is not available for the Trinity River, the changes in modeled monthly average flows in January and February under Alternative 3 would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative, especially in areas with a confined channel where relatively minor

changes in flow have little influence on water depth or velocity, and no effects on egg/alevin incubation suitability are expected. The monthly average flows in the Trinity River below Lewiston Dam during the coho salmon egg/alevin incubation period would be too low to cause redd scour, and flow increases under Alternative 3 would therefore have no effect on the risk of redd scour relative to the No Action Alternative. The probability of redd scour in the primary coho salmon spawning reaches of the Trinity River is predicted to be less than 1% at flows up to 5,000 cfs (Gaeuman et al. 2023).

The modeled flow increases in December, January, and February of wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17) and average water temperatures under Alternative 3 would remain well below the upper water temperature objective of 56°F to protect spawning coho salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11; Assarian et al. 2023). Similarly, the modeled flow increases in December of above normal water years and in February of above normal water years would cause only negligible changes in modeled monthly average water temperature and there would be no change in the temperature suitability for spawning coho salmon or incubating eggs/alevins relative to the No Action Alternative. Compared with the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of coho salmon spawning and egg/alevin incubation habitat, with considerable variability related to channel geometry and its effect on flow-habitat relationships.

During the latter portion of the coho salmon incubation period, modeled monthly average flows under Alternative 3 would decrease by at least 5% in below normal water years in March (from 427 to 400 cfs) and in wet water years in April (from 1,035 to 957 cfs) compared with the No Action Alternative (Table O-246). Although WUA for egg/alevin incubation is not available for the Trinity River, the changes in modeled monthly average flows in March and April under Alternative 3 would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative, especially in areas with a confined channel where relatively minor changes in flow have little influence on water depth or velocity, and no impacts on egg/alevin incubation suitability are expected. The March and April decreases would have little impact on modeled monthly average water temperature in the Trinity River below Lewiston Dam and only negligible changes relative to the No Action Alternative (Figure O-19 and Figure O-17, respectively). From Lewiston Dam to North Fork Trinity River, water temperatures in March under Alternative 3 would remain below the 50°F upper suitability limit recommended by Washington State Department of Ecology (WDOE) (2002, as cited in Carter 2005) to support coho salmon incubation and emergence but could exceed the objective in April of dryer water years (Assarian et al. 2023). Compared with the No Action Alternative, the flow decreases in March and April under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of coho salmon spawning and egg/alevin incubation habitat, with considerable variability related to channel geometry and its impact on flow-habitat relationships.

Juvenile Rearing and Emigration

Naturally spawned juvenile coho salmon in the Trinity River emerge from the gravel and begin rearing in winter and early spring, with the first captures of young-of-year (age-0) coho salmon typically occurring in early March (U.S. Fish and Wildlife Service 2023, unpublished; Yurok

Tribe 2023, unpublished). Fry, juvenile, and subyearling coho salmon rearing in the Trinity River strongly prefer areas of slow water velocity and habitat with cover from woody material, overhanging vegetation, and clusters of aquatic vegetation (Hampton 1988, 1997; Chase et al. 2009; Pinnix et al. 2019). During high flows, young coho salmon use floodplains and other off-channel habitats (Chase et al. 2009). Rearing occurs year-round, typically over a period of 12–15 months, and the effects of flow and water temperature on rearing coho salmon therefore occur throughout the year. Most Trinity River coho salmon outmigrate to the ocean as yearling smolts between January and July (Harris et al. 2016; Petros et al. 2015; Petros et al. 2017).

Potential Changes to Coho Salmon from Seasonal Operations

Seasonal operations under Alternative 3 would have spatially and temporally variable effects on the availability and suitability of juvenile rearing and emigration habitat for coho salmon. Compared to the No Action Alternative, substantial differences (greater than 5%) in modeled monthly average flows would occur in some water year types in December–April (Table O-246). In all other months and water year types, there would be little or no difference in monthly average flow between Alternative 3 and the No Action Alternative, and no effects on coho salmon are expected.

In December, the increase in modeled monthly average flow in wet water years from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 (Table O-246) would result in a slight increase in WUA for coho salmon fry and a decrease in WUA for coho salmon juveniles in the reach from Lewiston Dam to Dutch Creek, a slight decrease in fry and juvenile WUA in the reach from Dutch Creek to North Fork Trinity River, no change in fry WUA and a decrease in juvenile WUA in the reach from North Fork Trinity River to South Fork Trinity River, and a slight increase in fry WUA and no change in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The modeled December flow increase in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 would have similar effects on WUA for coho salmon fry and juveniles as the December flow increase in wet water years. In January and February in wet water years, modeled flow increases from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3 (January) and from 1,843 cfs under the No Action Alternative to 1,962 cfs under Alternative 3 (February) would result in an increase in fry and juvenile WUA in the reach from Lewiston Dam to Dutch Creek, no change in fry and juvenile WUA in the reach from Dutch Creek to North Fork Trinity River, a slight increase in fry WUA and a slight decrease in juvenile WUA in the reach from North Fork Trinity River to South Fork Trinity River, and no change in fry and juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the increase in modeled monthly average flow from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3 would have the same effect on fry and juvenile coho salmon WUA as the monthly flow changes in December of wet water years. In locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships (Cooper-Hertel et al. 2022). Consequently, coho salmon WUA in all reaches is likely to vary spatially with channel confinement and incision.

The modeled flow increases in December, January, and February of wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam, but there would be no substantial differences relative to the No Action Alternative (Figure O-17), and monthly average water temperatures throughout the Trinity River under Alternative 3 would remain well below the 59°F water temperature objective for emigrating juvenile coho salmon (smolts) recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in December, January, and February would remain below the 59°F objective throughout the Trinity River under a wide range of flow scenarios (Asarian et al. 2023), and there would be no change in the temperature suitability for rearing or emigrating coho salmon under Alternative 3 relative to the No Action Alternative. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 3 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the coho salmon juvenile rearing and emigration period at downstream locations in some water year types under Alternative 3, water temperatures and the potential impacts on coho salmon would not differ from the No Action Alternative. Compared with the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of coho salmon rearing and emigration habitat, with considerable variability related to channel geometry and its impact on flow-habitat relationships. Substantial impacts on coho salmon would be unlikely.

Modeled monthly average flows under Alternative 3 would decrease in below normal water years in March (from 427 to 400 cfs) and in wet water years in April (from 1,035 to 957 cfs) compared to the No Action Alternative (Table O-246). The March flow reduction would increase WUA for fry and juvenile coho salmon in all reaches of the Trinity River relative to the No Action Alternative, while the April flow reduction would have variable effects on fry and juvenile WUA (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In the reach from Lewiston Dam to Dutch Creek, the April flow reduction would slightly reduce fry WUA and increase juvenile WUA. In downstream reaches, the April flow reduction would increase fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and from North Fork Trinity River to South Fork Trinity River. In the reach from South Fork Trinity River to Weitchpec, the April flow reduction would slightly reduce fry WUA and would not change juvenile WUA relative to the No Action Alternative. The March and April flow reductions would have little effect on modeled monthly average water temperature in the Trinity River below Lewiston Dam and only negligible changes relative to the No Action Alternative (Figure O-19 and Figure O-17, respectively). Throughout the Trinity River, monthly average water temperatures in March and April under Alternative 3 would remain well below the 59°F upper water temperature objective recommended for emigrating juvenile coho salmon (smolts) in normal and wetter water years and the 62.6°F objective in dry and critically dry water years (U.S. Fish and Wildlife Service and Hoopa Valley Tribe 1999; Assarian et al. 2023) and there would be no change relative to the No Action Alternative.

Compared with the No Action Alternative, the change in seasonal operations in March and April under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of coho salmon rearing and emigration habitat, with considerable variability related to channel geometry and its impact on flow-habitat relationships. Substantial impacts on coho salmon would be unlikely.

Adult Upstream Migration and Holding

From August to January, coho salmon return from the ocean through the Klamath River Estuary to the Trinity River, moving upstream toward spawning habitat. Based on recent weir counts, the date of peak abundance of upstream-migrating coho salmon in the Trinity River ranges from late September to mid-November (Kier et al. 2018, 2019, 2020, 2021, 2022). After completing their upstream migration, mature coho salmon may hold for days, weeks, or sometimes months before spawning. Because most spawning occurs in November and December, the effects of flow and water temperature on migrating and holding coho salmon would primarily occur from August through December.

Potential Changes to Coho Salmon from Seasonal Operations

During the coho salmon upstream migration and holding period there would be no differences in modeled monthly average flow between Alternative 3 and the No Action Alternative in August, September, or October; a negligible difference in November; and slightly greater but variable differences in December and January. Differences would vary by month and water year type and are described in detail in the preceding sections and shown in Table O-246. These differences may result in minor, short-term changes in physical habitat conditions but modeled monthly average flows from August through January when adult coho salmon are migrating and holding would be equal to or greater than 300 cfs in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and holding habitat to support pre-spawning coho salmon.

Modeled monthly average flows in August and September, when adult coho salmon begin migrating upstream from the ocean and water temperatures are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 3 as under the No Action Alternative (Table O-246). Under both alternatives, modeled average August and September flows of 760 cfs in wet water years and 863 cfs in all other water year types would maintain suitable water temperatures for adult upstream migration (60°F in August and early September and 56°F in late September; Table O-11) in the Trinity River at Lewiston Dam (Figure O-17). Although downstream warming during August and September could result in unsuitable water temperatures for migrating coho salmon at some locations, the likelihood of this occurring would be the same under Alternative 3 as under the No Action Alternative due to the identical flows.

During the late September to mid-November peak adult migration period, the modeled monthly average flows under Alternative 3 would be the same as the No Action Alternative except for a negligible increase of 6 cfs in November of above normal water years (Table O-246). In December and January, substantial flow differences (greater than 5%) between the two alternatives would occur in December of wet water years (from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3), in December of below normal water years (from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3), and in January of wet water years (from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3).

None of the modeled December and January flow differences would have substantial impacts on modeled monthly average water temperature at Lewiston Dam in the respective water year types (Figure O-17 and Figure O-21) and there would be no impacts on water temperature suitability for coho salmon migration and holding relative to the No Action Alternative. Compared with the No Action Alternative, the differences in modeled monthly average flows and associated water temperature differences under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of coho salmon upstream migration and holding habitat and substantial impacts on coho salmon would be unlikely.

O.6.26 Upper Klamath-Trinity River Spring-run Chinook Salmon ESU

O.6.26.1 Trinity River

Spawning and Egg/Alevin Incubation

Most spring-run Chinook salmon in the Trinity River spawn from late September to mid-November, with a peak in October (Gough et al. 2021a,b). At optimal intragravel temperatures (41–55°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another 4–6 weeks (Healey 1991, Moyle 2002). In the Trinity River, spring-run Chinook salmon incubation and emergence typically occurs through February (Leidy and Leidy 1984). The effects of flow and water temperature on spring-run Chinook salmon spawning and egg/alevin incubation may therefore occur from approximately mid-September through February.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Under Alternative 3, modeled monthly average flows in the Trinity River below Lewiston Dam from September through February when spring-run Chinook salmon egg/alevin incubation occurs would be equal to or greater than 300 cfs in all water year types, and substantially greater in the wettest water years in some months, to provide suitable conditions for incubation and emergence (Table O_Trin_Alt3). From May through November, monthly average flows under Alternative 3 would be the same as the No Action Alternative or would not differ substantially (by more than 5%) in any month or water year type. Modeled monthly average flows in December of wet and below normal water years, January of wet water years, and February of wet and above normal water years would be at least 5% greater than the No Action Alternative. Monthly average flows in March of below normal water years and April of wet water years would be at least 5% less than the No Action Alternative. Only the December, January, and February differences would occur during the spring-run Chinook salmon spawning and egg/alevin incubation period. These changes would have variable effects on the availability and suitability of spawning and incubation habitat for spring-run Chinook salmon.

In December when spring-run Chinook salmon eggs/alevins may be incubating in the Trinity River, modeled monthly average flow would increase in wet water years from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 and in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 (Table O-246). In January when spring-run Chinook salmon eggs/alevins may be incubating, monthly average flow would increase in wet water years from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3. In February when spring-run Chinook salmon eggs/alevins may be incubating, monthly average flow would increase in wet water years from 1,843 cfs under the No Action

Alternative to 1,962 cfs under Alternative 3 and in above normal water years from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3.

The increased December–February average flows are not expected to reduce suitability for incubating Chinook salmon eggs/alevins, and the December flow increase may reduce risk of redd superimposition by later-spawning fall-run Chinook salmon and coho salmon. In all reaches of the Trinity River, the effects of flow changes on spawning and incubation suitability are likely to vary spatially with channel confinement and incision (Goodman et al. 2018). Where the channel is naturally unconfined and not overly incised and where channel restoration has removed remnant riparian berms and reduced legacy channel confinement and incision, a stronger positive relationship between flow and salmonid habitat suitability, particularly for flows of approximately 300–1,200 cfs, can be expected than in areas of greater channel confinement (see Section O.4.24.1.1 for a detailed discussion). This is mainly a result of increasing habitat area, which also provides more space for redds and reduces the risk of redd superimposition by later-spawning salmonids. The monthly average flows in the Trinity River below Lewiston Dam during the spring-run Chinook salmon egg/alevin incubation period would be too low to cause redd scour, and modeled monthly average flow increases under Alternative 3 would therefore have no impact on the risk of redd scour relative to the No Action Alternative. The probability of redd scour in the primary salmon spawning reaches of the Trinity River is predicted to be less than 1% at flows up to 5,000 cfs (Gaeuman et al. 2023).

The flow increases in December, January, and February of wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17). Modeled monthly average water temperatures under Alternative 3 would remain well below the upper water temperature objective of 56°F (Table O-11) to protect spring-run Chinook salmon eggs/alevins in the reach from Lewiston Dam to the North Fork Trinity River (Assarian et al. 2023). Similarly, the flow increases in December in below normal water years and February in above normal water years would cause only negligible changes in water temperature and there would be no change in the temperature suitability for incubating spring-run Chinook salmon eggs/alevins relative to the No Action Alternative.

Compared with the No Action Alternative, the increased monthly average flows in December, January, and February under Alternative 3 would likely have minor impacts on the availability and suitability of spring-run Chinook salmon spawning and incubation habitat in the Trinity River. Overall, the impacts in the reaches most heavily used by spawning spring-run Chinook salmon adults and incubating eggs/alevins would likely be negligible or slightly beneficial, with spatial variability related to channel geometry and its impact on flow-habitat relationships.

Juvenile Rearing and Emigration

In the Trinity River, spring-run Chinook salmon fry emerge from the gravel beginning in December and most emergence is complete by the end of February (Leidy and Leidy 1984). Fry and juvenile Chinook salmon rearing in the Trinity River preferentially use areas of relatively slow water velocity and habitat with woody material, undercut banks, and other complex cover (Hampton 1988, Pinnix et al. 2019). Naturally spawned juvenile spring-run Chinook salmon typically outmigrate as sub-yearlings from the Trinity River and occasionally as yearlings. Hatchery releases of spring-run Chinook salmon also include mostly sub-yearlings and some

yearling releases in spring and fall, respectively. Peak outmigration of natural and hatchery origin juveniles occurs in May, June, and July based on monitoring in the lower Trinity River near the town of Willow Creek (Harris et al. 2016; Petros et al. 2017). The effects of flow and water temperature on rearing and emigrating spring-run Chinook salmon may therefore occur from December through July.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Substantial (greater than 5%) differences in modeled monthly average Trinity River flows between Alternative 3 and the No Action Alternative would occur in December–April of below normal and wetter water years. In June of wet water years there would be a minor (less than 5%) decrease in modeled monthly average flow under Alternative 3 compared with the No Action Alternative. These changes would have variable effects on the suitability for rearing and emigrating spring-run Chinook salmon in the Trinity River. In all other months and water year types there would be little or no difference in monthly average flow between Alternative 3 and the No Action Alternative and no effects on spring-run Chinook salmon would be expected.

Modeled monthly average flow in December of wet water years would increase from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 (Table O_Trin_Alt3) and may result in changes in observed and predicted WUA for fry and juvenile spring-run Chinook salmon that would vary by reach (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). From Lewiston Dam to Dutch Creek, fry WUA would increase and juvenile WUA would decrease. In the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, WUA for both fry and juveniles would decrease. From South Fork Trinity River to Weitchpec, fry WUA would increase and juvenile WUA would decrease slightly (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In January and February of wet water years, modeled monthly average flow increases from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3 (January) and from 1,843 cfs under the No Action Alternative to 1,962 cfs under Alternative 3 (February) would result in increases in fry and juvenile WUA from Lewiston Dam to Dutch Creek, decreases in fry and juvenile WUA from Dutch Creek to North Fork Trinity River, an increase in fry and decrease in juvenile WUA from North Fork Trinity River to South Fork Trinity River, and a slight increase in fry and slight decrease in juvenile WUA from South fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The modeled December flow increase in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 would increase fry WUA and decrease juvenile WUA in the reach from Lewiston Dam to Dutch Creek, decrease fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and would increase fry WUA and decrease juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the increase in modeled monthly average flow from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3 would have the same effect on fry and juvenile spring-run Chinook salmon WUA as the monthly flow changes in December of wet water years.

Modeled monthly average flows under Alternative 3 would decrease in below normal water years in March (from 427 to 400 cfs) and in wet water years in April (from 1,035 to 957 cfs) compared with the No Action Alternative (Table O-246). The modeled March flow reduction would increase WUA for fry and juvenile spring-run Chinook salmon in all reaches of the Trinity

River relative to the No Action Alternative, while the April flow reduction would have variable effects on fry and juvenile WUA (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In the reach from Lewiston Dam to Dutch Creek, the modeled April flow reduction would slightly reduce fry WUA and increase juvenile WUA. In downstream reaches, the April flow reduction would increase fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and from North Fork Trinity River to South Fork Trinity River. In the reach from South Fork Trinity River to Weitchpec, the modeled April flow reduction would reduce fry WUA and increase juvenile WUA relative to the No Action Alternative.

Where the channel is naturally unconfined and not overly incised and in locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships and rearing WUA in some restored areas may exhibit a stronger positive relationship to flow up to approximately 3,500 cfs (Cooper-Hertel et al. 2022). Consequently, spring-run Chinook salmon WUA in all reaches is likely to vary spatially with channel confinement and incision and in WUA in restored areas may be greater than described in U.S. Fish and Wildlife Service and Hoopa Valley Tribe (1999). See Section O.4.24.1.1 for additional details. The changes in WUA for spring-run Chinook salmon fry and juveniles may have short-term, spatially variable effects on the ability of these life stages to access cover and preferred habitat that would occur in certain water year types during five months of the eight-month rearing and emigration period and in some reaches of the Trinity River.

The modeled flow increases in December, January, and February of wet water years may result in negligible changes in monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17). Similarly, the modeled flow increases in December of below normal water years and February of above normal water years would have little or no effect on modeled monthly average water temperatures in the Trinity River below Lewiston Dam relative to the No Action Alternative (Figure O-19 and Figure O-18, respectively). From December through February, modeled monthly average water temperatures under Alternative 3 would remain well below the 62.6°F water temperature objective for emigrating juvenile spring-run Chinook salmon recommended for normal and wetter water year types and the 68°F objective recommended for dry and critically dry water year types (U.S. Fish and Wildlife Service and Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that Trinity River water temperatures in December–February would remain below both objectives under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating spring-run Chinook salmon under Alternative 3 relative to the No Action Alternative.

The modeled March and April flow reductions under Alternative 3 would have minor effects on modeled monthly average water temperature in the Trinity River below Lewiston Dam relative to the No Action Alternative (Figure O-19 and Figure O-17, respectively). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that Trinity River water temperatures in March and April under the modeled monthly average flows under Alternative 3 would likely remain below the recommended 62.6°F and 68°F water temperature objectives at Weitchpec (Assarian et al. 2023)

and there would be no change in the temperature suitability for rearing or emigrating spring-run Chinook salmon under Alternative 3 relative to the No Action Alternative.

The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 3 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the spring-run Chinook salmon juvenile rearing and emigration period at downstream locations in some water year types, water temperatures under Alternative 3 and the potential impacts on spring-run Chinook salmon would not differ substantially from the No Action Alternative. Compared with the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of spring-run Chinook salmon rearing and emigration habitat, with considerable variability related to channel geometry and its impact on flow-habitat relationships.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon typically enter the Trinity River from April through September. By the end of July, most fish have arrived at the primary spawning reach, which extends from Lewiston Dam downstream to the confluence with the North Fork Trinity River. After entering freshwater, spring-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically begins in late September (Leidy and Leidy 1984; Gough et al. 2019, 2021a,b). The effects of flow and water temperature on migrating and holding spring-run Chinook salmon adults may therefore occur from April through September.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

During the spring-run Chinook salmon upstream migration and holding period, there would be a substantial (greater than 5%) difference in modeled monthly average flow between Alternative 3 and the No Action Alternative only in April, with a minor difference in June and no difference between the two alternatives in May, July, August, and September (Table O-246). The April difference may result in minor, short-term changes in physical habitat conditions but modeled monthly average flows during the majority of the spring-run Chinook salmon migration and holding period would be approximately 500 cfs or greater in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and holding habitat to support pre-spawning spring-run Chinook salmon.

Modeled monthly average flows in July, August, and September, when adult spring-run Chinook salmon are migrating and holding and water temperatures are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 3 as under the No Action Alternative (Table O-246). Under both alternatives, modeled average July flows would be approximately 500 cfs or greater in all water year types and substantially greater in wetter years. Modeled average flows in August and September would be 760 cfs in wet water years and 863 cfs in all other water year types. Under both alternatives, July–September flows would maintain suitable water temperatures for adult upstream migration (60°F from July 1 to September 14 and 56°F from September 15 to September 30 at Douglas City [RM 93.7]; Table O-11) (Assarian et al. 2023).

Although downstream warming during the warmest months and driest water year types could result in unsuitable water temperatures for migrating spring-run Chinook salmon at some locations (Buxton 2023), the likelihood of this occurring would be the same under Alternative 3 as under the No Action Alternative because modeled monthly average flows in July–September would be the same under both alternatives. In April and June, modeled decreases in monthly average flows under Alternative 3 would occur only in the wettest water year types when flows in the Trinity River below Lewiston Dam are relatively high and the impact on water temperature, as well as differences between Alternative 3 and the No Action Alternative, would likely be minor (Assarian et al. 2023).

Compared with the No Action Alternative, the differences in monthly average flows and associated water temperature differences under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of spring-run Chinook salmon upstream migration and holding habitat.

O.6.27 Upper Klamath-Trinity River Fall-run Chinook Salmon ESU

O.6.27.1 Trinity River

Spawning and Egg/Alevin Incubation

Most fall-run Chinook salmon in the Trinity River spawn from late October to December, with a peak in spawning occurring in November (Myers et al. 1998, Leidy and Leidy 1984). Optimal spawning temperatures are reported to be less than 55.4°F (Moyle 2002). At optimal intragravel temperatures (43–54°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another four to six weeks (Moyle 2002). In the Trinity River, fall-run Chinook salmon incubation and emergence typically occurs from December through late February (Leidy and Leidy 1984). The effects of flow and water temperature on fall-run Chinook salmon spawning and egg/alevin incubation may therefore occur from approximately mid-October through February.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Under Alternative 3, modeled monthly average flows in the Trinity River below Lewiston Dam from October through February when fall-run Chinook salmon may be spawning and eggs/alevins may be incubating would be equal to or greater than 300 cfs in all water year types, and substantially greater in the wettest water years in some months, to provide suitable conditions for spawning, incubation, and emergence (Table O_Trin_Alt3). From May through November, modeled monthly average flows under Alternative 3 would be the same as the No Action Alternative or would not differ substantially (by more than 5%) in any month or water year type. Modeled monthly average flows in December in wet and below normal water years, January in wet water years, and February in wet and above normal water years would be at least 5% greater than the No Action Alternative. Monthly average flows in March in below normal water years and April in wet water years would be at least 5% less than the No Action Alternative. Only the December, January, and February differences would occur during the fall-run Chinook salmon spawning and egg/alevin incubation period. These changes would have variable effects on the availability and suitability of spawning and incubation habitat for fall-run Chinook salmon.

In December when fall-run Chinook salmon eggs/alevins may be incubating in the Trinity River, modeled monthly average flow would increase in wet water years from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 and in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 (Table O-246). In January when fall-run Chinook salmon eggs/alevins may be incubating, monthly average flow would increase in wet water years from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3. In February when fall-run Chinook salmon eggs/alevins may be incubating, monthly average flow would increase in wet water years from 1,843 cfs under the No Action Alternative to 1,962 cfs under Alternative 3 and in above normal water years from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3.

The increased December–February average flows are not expected to reduce suitability for incubating Chinook salmon eggs/alevins, and the December flow increase may reduce risk of redd superimposition by spring-run Chinook salmon and coho salmon. In all reaches of the Trinity River, the effects of flow changes on spawning suitability are likely to vary spatially with channel confinement and incision (Goodman et al. 2018). Where the channel is naturally unconfined and not overly incised and where channel restoration has removed remnant riparian berms and reduced legacy channel confinement and incision, a stronger positive relationship between flow and salmonid habitat suitability, particularly for flows of approximately 400–1,200 cfs, can be expected than in areas of greater channel confinement (see Section O.4.24.1.1 for a detailed discussion). This is mainly a result of increasing habitat area, which also provides more space for redds and reduces the risk of redd superimposition by later-spawning salmonids. The monthly average flows in the Trinity River below Lewiston Dam during the fall-run Chinook salmon egg/alevin incubation period would be too low to cause redd scour, and modeled monthly average flow increases under Alternative 3 would therefore have no impact on the risk of redd scour relative to the No Action Alternative. The probability of redd scour in the primary salmon spawning reaches of the Trinity River is predicted to be less than 1% at flows up to 5,000 cfs (Gaeuman et al. 2023).

The flow increases in December, January, and February of wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17). Modeled monthly average water temperatures under Alternative 3 would remain well below the upper water temperature objective of 56°F (Table O-11) to protect fall-run Chinook salmon eggs/alevins in the reach from Lewiston Dam to the North Fork Trinity River (Assarian et al. 2023). Similarly, the modeled average flow increases in December in below normal water years and February in above normal water years would cause only negligible changes in modeled monthly average water temperature and there would be no change in the temperature suitability for incubating fall-run Chinook salmon eggs/alevins relative to the No Action Alternative.

Compared with the No Action Alternative, the increased monthly average flows in December, January, and February under Alternative 3 would likely have minor impacts on the availability and suitability of fall-run Chinook salmon spawning and incubation habitat in the Trinity River. Overall, the impacts in the reaches most heavily used by spawning fall-run Chinook salmon adults and incubating eggs/alevins would likely be negligible or slightly beneficial, with spatial variability related to channel geometry and its impact on flow-habitat relationships.

Juvenile Rearing and Emigration

In the Trinity River, fall-run Chinook salmon fry emerge from the gravel beginning in December and most emergence is complete by mid-April. Natural juvenile fall-run Chinook salmon primarily outmigrate as sub-yearlings from the Trinity River. Hatchery releases of fall-run Chinook salmon also include mostly smolts released primarily in late spring and fall. Peak outmigration occurs in March, April, and May but can extend to July based on monitoring in the lower Trinity River near the town of Willow Creek (Moyle 2002, Chesney and Yokel 2004). The effects of flow and water temperature on rearing and emigrating fall-run Chinook salmon may therefore occur primarily from December through July.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Substantial (greater than 5%) differences in modeled monthly average Trinity River flows between Alternative 3 and the No Action Alternative would occur in December–April of below normal and wetter water years. In June of wet water years there would be a minor (less than 5%) decrease in modeled monthly average flow under Alternative 3 compared with the No Action Alternative. These changes would have variable effects on the suitability for rearing and emigrating fall-run Chinook salmon in the Trinity River. In all other months and water year types there would be little or no difference in monthly average flow between Alternative 3 and the No Action Alternative and no effects on fall-run Chinook salmon would be expected.

Modeled monthly average flow in December of wet water years would increase from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 (Table O_Trin_Alt3) and may result in changes in observed and predicted WUA for fry and juvenile fall-run Chinook salmon that would vary by reach (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). From Lewiston Dam to Dutch Creek, fry WUA would increase and juvenile WUA would decrease. In the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, WUA for both fry and juveniles would decrease. From South Fork Trinity River to Weitchpec, fry WUA would increase and juvenile WUA would decrease slightly (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In January and February in wet water years, modeled monthly average flow increases from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3 (January) and from 1,843 cfs under the No Action Alternative to 1,962 cfs under Alternative 3 (February) would result in increases in fry and juvenile WUA from Lewiston Dam to Dutch Creek, decreases in fry and juvenile WUA from Dutch Creek to North Fork Trinity River, an increase in fry and decrease in juvenile WUA from North Fork Trinity River to South Fork Trinity River, and a slight increase in fry and slight decrease in juvenile WUA from South fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The modeled December flow increase in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 would increase fry WUA and decrease juvenile WUA in the reach from Lewiston Dam to Dutch Creek, decrease fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and would increase fry WUA and decrease juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the increase in modeled monthly average flow from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3 would have the same effect on fry and juvenile fall-run Chinook salmon WUA as the monthly flow changes in December in wet water years.

Modeled monthly average flows under Alternative 3 would decrease in below normal water years in March (from 427 to 400 cfs) and in wet water years in April (from 1,035 to 957 cfs) compared to the No Action Alternative (Table O-246). The modeled March flow reduction would increase WUA for fry and juvenile fall-run Chinook salmon in all reaches of the Trinity River relative to the No Action Alternative, while the April flow reduction would have variable effects on fry and juvenile WUA (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In the reach from Lewiston Dam to Dutch Creek, the modeled April flow reduction would slightly reduce fry WUA and increase juvenile WUA. In downstream reaches, the April flow reduction would increase fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and from North Fork Trinity River to South Fork Trinity River. In the reach from South Fork Trinity River to Weitchpec, the modeled April flow reduction would reduce fry WUA and increase juvenile WUA relative to the No Action Alternative.

Where the channel is naturally unconfined and not overly incised and in locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships and rearing WUA in some restored areas may exhibit a stronger positive relationship to flow up to approximately 3,500 cfs (Cooper-Hertel et al. 2022). Consequently, fall-run Chinook salmon WUA in all reaches is likely to vary spatially with channel confinement and incision and in WUA in restored areas may be greater than described in U.S. Fish and Wildlife Service and Hoopa Valley Tribe (1999). See Section O.4.24.1.1 for additional details. Compared with the No Action Alternative, the changes in WUA for fall-run Chinook salmon fry and juveniles may have short-term, spatially variable effects on the ability of these life stages to access cover and preferred habitat that would occur in certain water year types during the rearing and emigration period and in some reaches of the Trinity River.

The modeled flow increases in December, January, and February of wet water years may result in negligible changes in monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17). Similarly, the modeled flow increases in December of below normal water years and February of above normal water years would have little or no effect on modeled monthly average water temperatures in the Trinity River below Lewiston Dam relative to the No Action Alternative (Figure O-19 and Figure O-18, respectively). From December through February, modeled monthly average water temperatures under Alternative 3 would remain well below the 62.6°F water temperature objective for emigrating juvenile fall-run Chinook salmon recommended for normal and wetter water year types and the 68°F objective recommended for dry and critically dry water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that Trinity River water temperatures in December–February would remain below both objectives under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating fall-run Chinook salmon under Alternative 3 relative to the No Action Alternative.

The modeled March and April flow reductions under Alternative 3 would have minor effects on modeled monthly average water temperature in the Trinity River below Lewiston Dam relative to the No Action Alternative (Figure O-19 and Figure O-17, respectively). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that Trinity River water temperatures in March and April under the modeled monthly average flows under Alternative 3 would likely remain below the recommended 62.6°F and 68°F water temperature objectives at Weitchpec (Assarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating fall-run Chinook salmon under Alternative 3 relative to the No Action Alternative.

The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 3 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the fall-run Chinook salmon juvenile rearing and emigration period at downstream locations in some water year types, water temperatures under Alternative 3 and the potential impacts on fall-run Chinook salmon would not differ substantially from the No Action Alternative. Compared with the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of fall-run Chinook salmon rearing and emigration habitat, with considerable variability related to channel geometry and its impact on flow-habitat relationships. Substantial impacts on fall-run Chinook salmon would be unlikely.

Adult Upstream Migration and Holding

Adult fall-run Chinook salmon typically enter the Trinity River from September through October (Moyle et al. 2015). Two to four weeks after river entry, adults have made it to the primary spawning reach which extends from Lewiston Dam downstream to the confluence of the North Fork Trinity River. After entering freshwater, fall-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically ranges from the third week of September through November, peaking in October (Chensey and Knechtle 2012). The effects of flow and water temperature on migrating and pre-spawning fall-run Chinook salmon adults may therefore occur from August through November.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

During the fall-run Chinook salmon upstream migration and pre-spawning period, there would be no difference in modeled monthly average flow between Alternative 3 and the No Action Alternative, except a slight increase of 6 cfs in November in above normal water years (Table O-246). The November difference would be unlikely to change water depth or other habitat conditions that could affect migrating or pre-spawning adult fall-run Chinook salmon and there would be effects relative to the No Action Alternative.

Modeled monthly average flows in August, September, and October when adult fall-run Chinook salmon are migrating and holding would be the same under Alternative 3 as under the No Action Alternative (Table O-246). Under both alternatives, modeled average August and September flows would be approximately 760 cfs or greater in all water year types and substantially greater in wetter years. Modeled average flows in October would be 373 cfs in all water year types. Under both alternatives, September through October flows would maintain suitable water temperatures for adult upstream migration (60°F to 56°F in September, and <56°F from August through October at Douglas City [RM 93.7]; Table O-11) (Assarian et al. 2023).

Compared with the No Action Alternative, the differences in monthly average flows and associated water temperature differences under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of fall-run Chinook salmon upstream migration and pre-spawning habitat and substantial impacts on fall-run Chinook salmon would be unlikely.

O.6.28 Klamath Mountains Province Steelhead DPS

O.6.28.1 Trinity River

Monthly average flows in the Trinity River below Lewiston Dam would generally be similar under Alternative 3 to flows under the No Action Alternative. Minor differences in monthly average flows between Alternative 3 and the No Action Alternative would occur in November through April and in June of some water year types, with most differences less than 5%. Like the No Action Alternative, seasonal flow releases under Alternative 3 are expected to maintain a low risk of disease outbreaks for steelhead by maintaining minimum flows and relatively cool water temperatures.

Spawning and Egg/Alevin Incubation

Spawning across run types in the Trinity River may occur anytime from December through May so effects of flow and water temperature on spawning may occur during this period.

Steelhead eggs and alevins across run types in the Trinity River may be present in the gravel from December through June, so effects of flow and water temperature on steelhead eggs and alevins may occur during this period.

Potential Changes to Steelhead from Seasonal Operations

Under Alternative 3, modeled monthly average flows in the Trinity River below Lewiston Dam in December of wet and below normal water years, January of wet water years, and February of wet and above normal water years would be at least 5% greater than the No Action Alternative (Table O_Trin_Alt3). Monthly average flows in March of below normal water years and April of wet water years would be at least 5% less than the No Action Alternative. These changes would have variable effects on the availability and suitability of spawning and egg/alevin incubation habitat for steelhead. From May through November, modeled monthly average flows under Alternative 3 would be the same as the No Action Alternative or would not differ substantially (by more than 5%) in any month or water year type.

In December, modeled monthly average flow would increase in wet water years from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 and in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 (Table O-246). In January, modeled monthly average flow would increase in wet water years from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3. In February, modeled monthly average flow would increase in wet water years from 1,843 cfs under the No Action Alternative to 1,962 cfs under Alternative 3 and in above normal water years from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3.

The modeled December flow increases may result in a negligible increase in WUA for steelhead spawning in the reach from Dutch Creek to North Fork Trinity River in wet water years but would have little to no change in WUA for steelhead spawners in downstream reaches or in below normal water years (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The modeled January flow increase would not change WUA for steelhead spawning in the reach from Dutch Creek to South Fork Trinity River but may negligibly increase spawning WUA from South Fork Trinity to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The modeled February flow increases would have little to no change in spawning WUA.

The modeled flow increases in December, January, and February of wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17) and average water temperatures under Alternative 3 would remain well below the upper water temperature objective of 56°F to protect spawning coho salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11). Similarly, the modeled flow increases in December of above normal water years and February of above normal water years would cause only negligible changes in modeled monthly average water temperature and there would be no change in the temperature suitability for spawning steelhead or incubating eggs/alevins relative to the No Action Alternative. Compared to the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of steelhead spawning and egg/alevin incubation habitat, with considerable variability related to channel geometry and its effect on flow-habitat relationships.

Modeled monthly average flows under Alternative 3 would decrease by at least 5% in below normal water years in March (from 427 to 400 cfs) and in wet water years in April (from 1,035 to 957 cfs) compared to the No Action Alternative (Table O-246). The March flow decrease would result in a slight increase in WUA for spawning steelhead in the reach from North Fork Trinity to South Fork Trinity, and little to no change in WUA from Lewiston Dam to North Fork Trinity and South Fork Trinity to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The April flow decrease would result little to no change in WUA for spawning steelhead in any of the reaches The March and April decreases would have little impact on modeled monthly average water temperature and only negligible changes relative to the No Action Alternative (Figure O-19 and Figure O-17, respectively). Water temperatures in March and April under Alternative 3 would remain well below the 56°F upper water temperature objective for spawning salmon. Compared to the No Action Alternative, the flow decreases in March and April under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of steelhead spawning and egg/alevin incubation habitat.

Juvenile Rearing and Emigration

Rearing or moving (migrating or redistributing) fry and/or juveniles can occur downstream of Lewiston Dam any time of year with three peak emigration times in March, May/June, and October/November.

Potential Changes to Steelhead from Seasonal Operations

Seasonal operations under Alternative 3 would have spatially and temporally variable effects on the availability and suitability of juvenile rearing and emigration habitat for steelhead. Compared to the No Action Alternative, substantial differences (greater than 5%) in modeled monthly average flows would occur in some water year types in December–April (Table O-246). In all other months and water year types there would be little or no difference in monthly average flow between Alternative 3 and the No Action Alternative and no effects on steelhead would be expected in those months (May–November).

In December, the increase in modeled monthly average flow in wet water years from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 (Table O-246) would result in little to no change in measured or estimated WUA for steelhead fry or juveniles from Lewiston Dam to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The modeled December flow increase in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 would have similar effects on WUA for steelhead fry and juveniles as the December flow increase in wet water years.

In January and February in wet water years, modeled flow increases from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3 (January) and from 1,843 cfs under the No Action Alternative to 1,962 cfs under Alternative 3 (February) would result in an increase in measured and predicted fry WUA in the reach from Lewiston Dam to Dutch Creek and South Fork Trinity to Weitchpec and little to no change in juvenile WUA (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

In February of above normal water years, the increase in modeled monthly average flow from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3 would have little to no effect on fry and juvenile steelhead WUA.

In locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships (Cooper-Hertel et al. 2022). Consequently, steelhead WUA in all reaches is likely to vary spatially with channel confinement and incision.

The modeled flow increases in December, January, and February of wet water years may result in negligible changes in monthly average water temperature in the Trinity River below Lewiston Dam. Average water temperatures under Alternative 3 would remain well below the 59°F water temperature objective for emigrating juvenile salmonids recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in November, December, February, and March would remain below the 59°F objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating

steelhead trout under Alternative 3 relative to the No Action Alternative. Similarly, the flow increases in December of above normal water years and February of above normal water years would cause only negligible changes in modeled monthly average water temperature and there would be no change in the temperature suitability for spawning steelhead or incubating eggs/alevins relative to the No Action Alternative. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 3 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of some water year types under Alternative 3, water temperatures and the potential effects on steelhead would not differ from the No Action Alternative. Compared to the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of steelhead trout rearing and emigration habitat, with considerable variability related to channel geometry and its effect on flow-habitat relationships.

Modeled monthly average flows under Alternative 3 would decrease in below normal water years in March (from 427 to 400 cfs) and in wet water years in April (from 1,035 to 957 cfs) compared to the No Action Alternative (Table O-246). The March flow reduction would increase WUA for fry and juvenile steelhead overall across all reaches of the Trinity River relative to the No Action Alternative, while the April flow reduction would have little to no change on fry and juvenile WUA (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

The March and April flow reductions would have little effect on modeled monthly average water temperature and only negligible changes relative to the No Action Alternative (Figure O-19 and Figure O-17, respectively). Modeled monthly average water temperatures in March and April under Alternative 3 would remain well below the 59°F upper water temperature objective for emigrating juvenile salmonids. Compared to the No Action Alternative, the change in seasonal operations in March and April under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of steelhead rearing and emigration habitat, with considerable variability related to channel geometry and its impact on flow-habitat relationships. Substantial adverse impacts on steelhead fry and juveniles would be unlikely and Alternative 3 may slightly benefit fry and juvenile habitat in some water years.

Adult Upstream Migration and Holding

Consistent adult monitoring data are limited by environmental conditions and challenges in overlapping populations with different run timing, kelting or “runbacks”, and half pounders but summer/fall steelhead (stream-maturing steelhead) are thought to return from the ocean about April through November and hold for varying lengths of time in the Klamath-Trinity watershed (Moyle et al. 2017, Moyle et al. 2015, Pinnix et al 2007). Winter steelhead (ocean-maturing steelhead) can return from the ocean about November through March (Moyle et al. 2017, Moyle et al. 2015, Pinnix et al 2007). Given the overlapping run timings and varying life history strategies, adults at various stages of maturation can enter the Klamath-Trinity watershed, hold in Trinity River, and/or migrate up or down Trinity River and into tributaries in any month of the year.

Potential Changes to Steelhead from Seasonal Operations

Alternative 3 relative to the No Action Alternative would have differences in flow that vary by month and water year type, and are described in detail in the preceding sections and shown in Table O-246. These differences may result in minor, short-term changes in physical habitat conditions but monthly average flows from would be equal to our greater than 300 cfs in all months and all water year types, and substantially greater in some months and water years, to provide a range of suitable depth and velocity for upstream passage as well as access to cover and holding habitat to support pre-spawning steelhead.

Seasonal operations under Alternative 3 would have spatially and temporally variable effects on the availability and suitability of adult holding habitat for steelhead. Compared to the No Action Alternative, substantial differences (greater than 5%) in modeled monthly average flows would occur in some water year types in December–April of Alternative 3 (Table O-246). In all other months and water year types there would be little or no difference in monthly average flow between Alternative 3 and the No Action Alternative and no effects on steelhead would be expected in those months (May–November).

In December, the increase in modeled monthly average flow in wet water years from 1,133 cfs under the No Action Alternative to 1,252 cfs under Alternative 3 (Table O-246) would result in a decrease in WUA for steelhead adult holding from Dutch Creek to North Fork Trinity River and little to no change in downstream reaches (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999) (WUA for adult holding over 800 cfs is not available for the reach between Lewiston Dam and Dutch Creek).

The modeled December flow increase in below normal water years from 931 cfs under the No Action Alternative to 997 cfs under Alternative 3 would result in negligible decreases from Dutch Creek to North Fork Trinity and South Fork Trintiy to Weitchpec and little to no change from North Fork Trinity to South Fork Trinity (WUA for adult holding over 800 cfs is not available for the reach between Lewiston Dam and Dutch Creek).

In January and February in wet water years, modeled flow increases from 1,872 cfs under the No Action Alternative to 2,007 cfs under Alternative 3 (January) and from 1,843 cfs under the No Action Alternative to 1,962 cfs under Alternative 3 (February) would result in negligible decreases in measured and predicted adult holding WUA in the reach from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999) (WUA is not available between Lewiston Dam and Dutch Creek).

In February of above normal water years, the increase in modeled monthly average flow from 1,194 cfs under the No Action Alternative to 1,302 cfs under Alternative 3 would result in negligible decreases in adult steelhead holding WUA from Dutch Creek to North Fork Trinity and from South Fork Trinity to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999) (WUA is not available between Lewiston Dam and Dutch Creek).

In locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships (Cooper-Hertel et al. 2022). Consequently, steelhead WUA in all reaches is likely to vary spatially with channel confinement and incision.

The modeled flow increases in December, January, and February of wet water years may result in negligible changes in monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative (Figure O-17) and modeled monthly average water temperatures under Alternative 3 would remain well below the 59°F water temperature objective for emigrating juvenile salmon recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in November, December, February, and March would remain below the 59°F objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for migrating and holding adult steelhead under Alternative 3 relative to the No Action Alternative. Similarly, the flow increases in December of above normal water years and February of above normal water years would cause only negligible changes in modeled monthly average water temperature and there would be no change in the water temperature suitability for adult steelhead migration and holding relative to the No Action Alternative. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 3 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of some water year types under Alternative 3, water temperatures and the potential effects on steelhead would not differ from the No Action Alternative. Compared to the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of adult steelhead migration and holding habitat, with considerable variability related to channel geometry and its effect on flow-habitat relationships.

Modeled monthly average flows under Alternative 3 would decrease in below normal water years in March (from 427 to 400 cfs) and in wet water years in April (from 1,035 to 957 cfs) compared to the No Action Alternative (Table O-246). The March flow reduction would increase WUA for fry and juvenile steelhead overall across all reaches of the Trinity River relative to the No Action Alternative, while the April flow reduction would have little to no change on fry and juvenile WUA (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

The March and April flow reductions would have little effect on modeled monthly average water temperature and only negligible changes relative to the No Action Alternative (Figure O-19 and Figure O-17, respectively). Modeled monthly average water temperatures in March and April under Alternative 3 would remain well below the 59°F upper water temperature objective for migrating and holding adult steelhead. Compared to the No Action Alternative, the change in seasonal operations in March and April under Alternative 3 would cause only negligible changes in factors affecting the availability or suitability of adult steelhead migration and holding habitat, with considerable variability related to channel geometry and its effect on flow-habitat relationships.

Alternative 3 may result in some minor decreases overall in steelhead adult holding habitat relative to the No Action Alternative but substantial adverse impacts are unlikely because this the changes are very small relative to the total amount of holding habitat and would only occur in a few months and only in some water year types.

O.6.29 Northern DPS Green Sturgeon

O.6.29.1 Trinity River

Spawning and Egg Incubation

Northern DPS green sturgeon adults spawn primarily from March through July, though most spawning takes place from April to June (O.1.2.5.1, *Green Sturgeon, Northern DPS*). Northern DPS green sturgeon eggs hatch approximately a week after fertilization, and optimal temperatures for incubation range from 51.8–62.6°F (Eenennaam et al. 2005).The effects analysis period for incubating eggs is considered to be the same as the spawning period due to the short incubation period and includes March through July.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be similar to flows under the No Action Alternative during spawning and egg incubation periods for green sturgeon. Under Alternative 3, reductions in flow greater 5% would occur in March of below normal years and in April of wet years compared to the No Action Alternative (Table O-246). Under Alternative 3 compared with the No Action Alternative, flow decreases would occur during the green sturgeon spawning and egg incubation period. These reductions in flows would likely be negligible for spawning habitat and egg incubation because flows would remain above 400 cfs.

Larval and Juvenile Rearing and Emigration

The northern DPS green sturgeon spawning period is from March through July, and the larval period is considered to be March through September. The juvenile stage of green sturgeon begins when metamorphosis of the larva is complete, typically about 45 days after hatching and approximately up to 2 cm TL. Juveniles (up to 150 cm TL) typically slowly migrate downstream, and rear in the lower Klamath River for up to a year or until approximately their first summer, and optimal growth temperatures range from 59–66.2°F (Moyle 2002; Mayfield and Cech, Jr. 2004). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near Burnt Ranch to the Klamath River Estuary (Section O.1.2.5.1, *Green Sturgeon, Northern DPS*). The effects analysis period for larval and juvenile life stages in the Trinity River should be considered April to September.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be similar to flows under the No Action Alternative during larval and juvenile rearing and emigration periods for green sturgeon. Under Alternative 3, monthly average flows greater than 5% in reduction would occur in April of wet years compared to the No Action Alternative (Table O-246). Under Alternative 3, monthly average flows would be almost identical to the No Action Alternative from April through September and would correspond to the No Action Alternative

flows that are currently managed to improve habitat conditions for anadromous fish. Alternative 3 monthly average flows would have no impacts to negligible impacts on larval and juvenile rearing and emigration of green sturgeon when compared with the No Action Alternative, even with reduced flows during wet years.

Green sturgeon larvae and juveniles are only known to occur within the lower 43 miles of the Trinity River, and after hatching, they begin to migrate downstream. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River, and results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling impact of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations are not likely to have a detectable influence on the water temperature suitability for larval and juvenile rearing and emigration of green sturgeon.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Trinity River from the Klamath River Estuary as early as February to make their way upstream to spawn in deep pools from the lower section of the mainstem Trinity River to the confluence with the Klamath River, approximately 43 miles to Gray's Falls near Burnt Ranch. After spawning, the adults remain in mainstem river pools for varying amounts of time, representing distinct migration patterns. Directly after spawning, 25% emigrate back to the Klamath River Estuary and ocean, but freshwater residency may last up to 199 days (Moyle 2002, Section O.1.3.2.5, *Green Sturgeon, Northern DPS*). With the extended adult holding period, effects analysis of flow and water temperature on adult upstream immigration, holding, and emigration may occur from February through December.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be similar to flows under the No Action Alternative. Under Alternative 3 increases in flow greater than 5% would occur in December of wet and above normal years, in January of wet years, and in February of wet and above normal years when compared to the No Action Alternative. Under Alternative 3, Flow reductions greater than 5% would occur in February of below normal years and in April of wet years (Table O-246).

During the green sturgeon upstream migration and holding period, generally flows would increase in February and flows would decrease in March and April under Alternative 3 compared with the No Action Alternative. The increase in flow in February of wet years would be negligible to beneficial because releases would provide adequate passage and pool holding habitats. The reduction in flows in April of wet years would be negligible to upstream migration and pool holding habitats because flows would remain above 957 cfs. Monthly average flows during the summer and fall months under Alternative 3 compared with the No Action Alternative would be identical and would provide adequate flows for downstream movements and pool habitats. Under Alternative 3, increased flows in December in wet and below normal water years would be beneficial to aid downstream migration and pool habitats.

O.6.30 Eulachon

O.6.30.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean

Spawning and Egg Incubation

Eulachon adults spawn from December and through May, with peak spawning occurring in March and April (O.1.2.6, *Eulachon*). Eulachon eggs hatch in 20 to 40 days depending on water temperature, with cooler temperatures leading to longer incubation times. Spawning is reported to occur at temperatures from 39 to 50°F; colder temperatures may stop migration (National Marine Fisheries Service 2017). The effects analysis period for eulachon spawning and egg incubation is December through June.

Potential Changes to Eulachon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative during the eulachon spawning and egg incubation periods, except in below normal water years in March and wet water years in April when the Alternative 3 flows would have a greater than 5% decrease compared to the No Action Alternative flows (Table O-246). The reduction in flows in wet and below normal years would likely be negligible for eulachon spawning habitat and egg incubation as flows would still be above 400 cfs. Alternative 3 flows would be greater than 5% higher than the No Action Alternative in wet years from December through February; during above normal years in February; and during below normal years in December (Table O-246). These higher flows are unlikely to have a detectable influence on habitat suitability for eulachon spawning and egg incubation in the lower Klamath River because of all the other water that enters the system during this time period. In addition to water released at Lewiston Dam, flows in this portion of the lower Klamath River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries).

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature within this section of the Klamath River below the confluence with the Trinity River is influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 3 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for spawning and egg incubation of eulachon in the Lower Klamath River.

Larval Emigration

Eulachon spawning period is from December through May and eggs hatch in 20 to 40 days, so the larval period is considered to be January through June. After hatching, larval eulachon are

quickly carried out to the ocean by river currents (Scott and Crossman 1973). Larval eulachon only remain in the Klamath River for about 5 days until they are washed out to sea. Larvae live on their yolk sac reserves after hatching —they do not feed while in fresh water (Gustafson et al. 2022). Effects of flow and water temperature on eulachon larvae may occur from January through June in the Klamath River.

Potential Changes to Eulachon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative during the eulachon larval emigration period, except in below normal water years in March and wet water years in April when the Alternative 3 flows would have a greater than 5% decrease than the No Action Alternative flows (Table O-246). The reduction in flows in wet and below normal years would likely be negligible for eulachon spawning habitat and egg incubation as flows would still be above 400 cfs. Alternative 3 flows would be greater than 5% higher than the No Action Alternative in wet years in January and February and during above normal years in February (Table O-246). Greater than 5% increases in flow under Alternative 3 compared to the No Action Alternative during wet and above normal years would provide increased water velocity and, similar to flow increases from spring freshets, could benefit eulachon larvae as they are washed out to the ocean.

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature within this section of the Klamath River below the confluence with the Trinity River is influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 3 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for eulachon larval emigration.

Adult Upstream Migration

The spawning migration period for adult eulachon in the Klamath River begins in December and continues until May, with peak migration occurring in March and April (Yurok Tribal Fisheries Program 1998; Larson and Belchik 1998, Section O.1.2.6). Eulachon distribution in the Trinity River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Eulachon are broadcast spawners most commonly over sand, though spawning substrates can range from silt, sand or gravel to cobble and detritus (California Department of Fish and Wildlife 2010; National Marine Fisheries Service 2017). Eulachon usually die after spawning. The effects analysis period for eulachon adult upstream migration is December through May.

Potential Changes to Eulachon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative during the eulachon adult upstream migration period, except in below normal water years in March and wet water years in April when the Alternative 3 flows would have a greater than 5% decrease than the No Action Alternative flows (Table O-246). The reduction in flows in wet and below normal years would likely be negligible for eulachon adult upstream migration as flows would still be above 400 cfs. Alternative 3 flows would be greater than 5% higher than the No Action Alternative in wet years from December through February; during above normal years in February; and during below normal years in December (Table O-246). These higher flows are unlikely to have a detectable influence on habitat suitability for eulachon adult upstream migration in the lower Klamath River because of all the other water that enters the system during this time period. In addition to water released at Lewiston Dam, flows in this portion of the lower Klamath River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries).

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature within this section of the Klamath River below the confluence with the Trinity River is influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 3 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for eulachon adult upstream migration.

O.6.31 Coastal Cutthroat Trout

O.6.31.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean

Spawning and Egg Incubation

Generally, spawning of anadromous and resident coastal cutthroat trout may occur from September to April (Moyle 2002). Coastal cutthroat trout are associated with shaded streams and instream cover with water temperatures below 64°F, while preferred temperatures range from 48–54°F, with spawning temperatures of 43–63°F. (Moyle 2002). Spawning habitat is typically found in headwater streams with 1–3 feet/sec flow velocities and unembedded small- to medium-sized gravel (0.08–4 inches) (Moyle 2002). Embryos hatch about 6–7 weeks following incubation and alevins emerge 1–2 weeks thereafter (Moyle 2002).

The effects analysis period for coastal cutthroat trout spawning and egg incubation is September through June.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative, except in below normal water years in March and wet water years in April when the Alternative 3 flows would be more than 5% lower than the No Action Alternative flows (Table O-246). The reduction in flows in wet and below normal years would be unlikely to reduce the availability or suitability of coastal cutthroat trout spawning pools and egg incubation habitat in adjacent tributaries as Trinity River flows do not impact tributaries. Alternative 3 flows would be greater than 5% higher than the No Action Alternative in wet years from December through February; during above normal years in February; and during below normal years in December (Table O-246). These increases in flows are not anticipated to have a detectable impact on coastal cutthroat trout spawning and egg incubation.

Seasonal operations under Alternative 3 are not expected to impact suitable habitat conditions for coastal cutthroat trout spawning and egg incubation in the Trinity River. Compared with the No Action Alternative, changes in the availability or suitability of coastal cutthroat trout juvenile spawning and egg incubation habitat under Alternative 3 would likely be negligible since Trinity River flows do not impact tributaries where coastal cutthroat trout spawn.

Juvenile Rearing and Emigration

Juvenile coastal cutthroat trout may spend anywhere from one to three years in freshwater to rear. Cutthroat fry are typically associated with slow water velocities (less than 1 foot/sec, while prefer <0.3 feet/sec), and trout are typically found in shaded streams with instream cover and water temperatures below 64°F, while preferred temperatures range from 48–54°F (Moyle 2002).

For the amphidromous life history, most coastal cutthroat trout leave their streams for the summer months and return to overwinter in fresh water, even as non-spawning fish (Moyle 2002). During outmigration, many of the trout migrate to estuaries or lagoons and if they do go to the ocean, they remain close to the coast (Moyle 2002). In a Klamath River tributary, yearling and older cutthroat emigration occurred mainly between April and June (Moyle 2002). For individuals that emigrated to an estuary, Wallace (2004) found that the residence time within the estuary ranged from 5 to 89 days, with a mean of 27 days. Resident coastal cutthroat trout will remain in freshwater their entire lives, rather than emigrating to a lagoon or estuary or the ocean.

The effects analysis period for coastal cutthroat trout juvenile rearing and emigration is April through June for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative, except in below normal water years in March and wet water years in April when the Alternative 3 flows would be more than 5% lower than the No Action Alternative flows (Table O-246). These reductions in flows in wet and below normal years would likely be negligible for coastal cutthroat trout juvenile rearing and emigration as flows would still be above 400 cfs and, with the combined influence of both the upper Klamath River and several tributaries that enter the Trinity River, are unlikely to have a

detectable influence on coastal cutthroat trout juvenile rearing and emigration. Alternative 3 flows would be greater than 5% higher than the No Action Alternative in wet years from December through February; during above normal years in February; and during below normal years in December (Table O-246). These increases in flows are not anticipated to have a detectable impact on coastal cutthroat trout juvenile rearing and emigration.

Water temperature and habitat conditions within the Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 3 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for coastal cutthroat trout juvenile rearing and emigration.

Seasonal operations under Alternative 3 are expected to maintain suitable habitat conditions for coastal cutthroat trout juvenile rearing and emigration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of coastal cutthroat trout juvenile rearing and emigration habitat would be minimal and unlikely to have adverse impacts on coastal cutthroat trout, and minor benefits to larval emigration in January and February.

Adult Holding and Migration

Migration of coastal cutthroat trout to freshwater typically occurs between August and October between the ages of one and five (Moyle 2002). While most anadromous salmonids die after completing spawning, coastal cutthroat may survive spawning, re-enter the ocean, and return the following year(s) to spawn up to five times (Moyle 2002). Overwintering coastal cutthroat trout prefer pools with cover (e.g., logs, undercut banks, boulders) (Moyle 2002).

The effects analysis period for coastal cutthroat trout adult holding and migration is August through October for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative, except in below normal water years in March and wet water years in April when the Alternative 3 flows would be more than 5% lower than the No Action Alternative flows (Table O-246). The reduction in flows in wet and below normal years would likely be negligible for coastal cutthroat trout adult holding and migration as flows would still be above 400 cfs and, with the combined influence of both the upper Klamath River and several tributaries that enter the Trinity River, are unlikely to have a detectable influence on coastal cutthroat trout adult holding and migration. Alternative 3 flows would be greater than 5% higher than the No Action Alternative in wet years from December through February; during above normal years in February; and during below normal years in December (Table O-246). These increases in flows are not anticipated to have a detectable impact on coastal cutthroat trout adult holding and migration.

Water temperature and habitat conditions within the Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 3 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for coastal cutthroat trout adult holding and migration.

Seasonal operations under Alternative 3 are expected to maintain suitable habitat conditions for coastal cutthroat trout adult holding and migration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of coastal cutthroat trout adult holding and migration habitat would be minimal and unlikely to have adverse impacts on coastal cutthroat trout.

O.6.32 Brown Trout

O.6.32.1 Trinity River

Spawning and Egg Incubation

Brown trout spawn in fall and winter, most commonly in November and December in California (Moyle 2002). Trout typically mature and spawn in their second or third year, but they may wait longer (7 or 8 years) (Moyle 2002). Adults begin selecting spawning locations when water temperatures are between 42.8–50ºF (Moyle 2002). Spawning habitat is comprised of pea- to walnut-sized gravel in less turbulent waters, which are typically found at pool tailouts (Moyle 2002). Embryos hatch in 7–8 weeks (ranging from 4–21 weeks), with alveins emerging three to six weeks later, depending on water temperature.

The effects analysis period for brown trout spawning and egg incubation is November through April.

Potential Changes to Brown Trout from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative during the brown trout spawning and egg incubation periods, except in below normal water years in March (6% reduction in flow) and wet water years in April (8% reduction in flow) (Table O-246). These increases in flows are not anticipated to have a detectable impact on brown trout spawning and egg incubation.

Seasonal operations under the Alternative 3 are expected to maintain suitable habitat conditions for brown trout spawning and egg incubation in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout spawning and egg incubation habitat would be minimal and unlikely to have adverse impacts on brown trout.

Juvenile Rearing and Emigration

The ideal temperature range for brown trout is between 53.6–68°F, with optimal growth between 62.6–64.4°F; they can survive for only short period at higher temperatures up to 84.2°F (Moyle 2002). Cold temperatures reduce brown trout's ability to effectively capture prey: when temperatures reduced from 58.5°F to 42.3°F the foraging effectiveness reduced from 96% to 53% (Watz and Piccolo 2010, as cited in Asarian et al. 2023).

In California, brown trout reach 2–3 inches in length their first year, 5–6 inches in their second year, 8–11 inches in their third, and 14–16 inches in their fourth year (Moyle 2002). Fry rear in edge-water habitat that is slow and shallow (<12 inches deep), with juveniles selecting riffles and pools with deeper water (20–30 inches), higher velocities (0.3–1.3 feet/second), and cover from overhead, rocks, and logs (Moyle 2002). It is uncertain the degree to which brown trout exhibit an anadromous life history in the Trinity River, with juveniles emigrating to the ocean, or are riverine (potamodromous) with juveniles emigrating further downstream while continuing to remain in freshwater. In Ireland, where they are native, brown trout juveniles emigrated to brackish or marine habitats throughout the year, with distinct seasonal peeks in spring (March through June) and fall (September through December) (Wynne et al. 2023).

The effects analysis period for brown trout juvenile rearing and emigration is January through December.

Potential Changes to Brown Trout from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative during the brown trout juvenile rearing and emigration periods, except in below normal water years in March (6% reduction in flow) and wet water years in April (8% reduction in flow) (Table O-246). These increases in flows are not anticipated to have a detectable impact on brown trout juvenile rearing and emigration.

Seasonal operations under the Alternative 3 are expected to maintain suitable habitat conditions for brown trout juvenile rearing and emigration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout juvenile rearing and emigration habitat would be minimal and unlikely to have adverse impacts on brown trout.

Adult Holding and Migration

Upstream migration occurs in fall and winter, prior to spawning, which most commonly occurs in November and December. Sullivan and Hilemean (2018) noted a shift in migration timing on the Trinity River to later in the season following the implementation of the Record of Decision (ROD) flows (2005-2011, 2017), as compared to the between baseline Pre-ROD flows (1982–2002). In rivers, adults will hold in a wide range of habitats, but are often associated with low velocity pools ranging from 2.3–11.5 feet deep that have cover (Moyle 2002).

The effects analysis period for brown trout adult holding and migration is January through December with migration primarily in November and December.

Potential Changes to Brown Trout from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative during the brown trout adult holding and migration periods, except in below normal water years in March (6% reduction in flow) and wet water years in April (8% reduction in flow) (Table O-246). These increases in flows are not anticipated to have a detectable impact on brown trout adult holding and migration.

Seasonal operations under the Alternative 3 are expected to maintain suitable habitat conditions for brown trout adult holding and migration in the Trinity River. Compared to the No Action Alternative, substantial changes in the availability or suitability of brown trout adult holding and migration habitat would be minimal and unlikely to have adverse impacts on brown trout.

O.6.33 Trinity Reservoir Species

O.6.33.1 Trinity Reservoir

Spawning and Egg Incubation

Coldwater fish species (rainbow trout, brown trout, Kokanee, and landlocked Chinook salmon) in the lake generally migrate into tributaries to spawn either during from December through March (rainbow trout), November–December (brown trout), or August through April (kokanee). Populations of rainbow trout, brown trout, and Kokanee are sustained through a combination of natural reproduction and fish hatchery stocking practices. Landlocked Chinook salmon do not typically reproduce (Perales et al. 2015) and are supported by annual stocking practices.

Warmwater fish species (smallmouth bass, largemouth bass, white catfish, and brown bullhead) typically rely on habitat in the lake during all life stages. In general, smallmouth and largemouth bass spawn from April through July in shallow water (1.5 feet to 6.0 feet deep) along the lake margins at water temperatures ranging from 55°F to 75°F (Moyle 2002). These nests are vulnerable to fluctuations in water levels. Rapid drops in water levels may cause guarding males to abandon the nests, increase predation, and limit water circulation and dissolved oxygen levels around the eggs (USFWS 1983, Habitat Suitability Information: Smallmouth Bass, FWS/OBS-82/10.36). White catfish spawning typically occurs during June and July when water temperatures exceed 68°F, but spawning can sometimes extend into September; spawning occurs in sandy substrate adjacent to cover (e.g., rocks, wood, or aquatic vegetation) and eggs hatch in about a week (Moyle 2002). Brown bullhead spawn from May through mid-July and will build their nests in sand or gravel near cover (Moyle 2002). Warmwater fish species in Trinity Lake are currently self-sustaining through natural reproduction.

The effects analysis period for coldwater fish species spawning and egg incubation is August through April. The effects analysis period for warmwater fish species spawning and egg incubation is April through September.

Potential Changes to Trinity Reservoir Fish Species from Seasonal Operations

Trinity Reservoir storage under Alternative 3 would generally be higher than storage under the No Action Alternative, except in wet years from April through December when Trinity Reservoir storage would be slightly lower than the No Action Alternative (Table O-247). Minor differences, less than 5%, in April–December during wet years would be unlikely to reduce the availability or suitability of spawning and egg incubation habitat for Trinity Reservoir fish species.

There would be increases in reservoir storage of greater than 5% under Alternative 3 compared with the No Action Alternative in below normal years from July through December; in dry years from August through November; and critically dry years from April through January. These increases in Trinity Reservoir storage between Alternative 3 and the No Action Alternative are not likely to have a negative impact on the water temperature and habitat suitability for spawning and egg incubation of Trinity Reservoir warmwater fish species benefit spawning and egg incubation under the assumption that an increase in reservoir volume could increase the amount of shallow edge habitat available where warmwater fish species build nests. Changes in reservoir storage between Alternative 3 and the No Action Alternative are not anticipated to impact coldwater fish species spawning and egg incubation because coldwater fish species migrate into tributaries to spawn.

Larval and Juvenile Rearing and Emigration

Rainbow trout fry emerge 3–4 weeks after fertilization and will remain in the gravel for about 2–3 weeks (Moyle 2002, USFWS 1984, Habitat Suitability Information: Rainbow Trout, FWS/OBS-82/10.60). Juvenile rainbow trout may spend two summers in their natal stream and two summers in a reservoir or lake before maturing. Brown trout fry typically hatch in 2 months, though it can range from one to five months depending on water temperature, and larvae will emerge from the gravel around one month later. Juveniles will spend several years in tributaries before emigrating to the reservoir where they will become sexually mature (Moyle 2002, Belica 2007).

Smallmouth and largemouth bass fry prefer shallow water and are vulnerable to fluctuations in water levels. These fry hatch in two to seven days and then spend another week in the nest. Larval bass stay in shallow water on the edge of vegetation (Moyle 2002). Rapid drops in water levels may cause stranding. Juvenile bass tend to live in deeper water habitats with submerged shelter (e.g., logs or boulders). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002).

The effects analysis period for both coldwater and warmwater fish species larval and juvenile rearing and emigration is January through December.

Potential Changes to Trinity Reservoir Fish Species from Seasonal Operations

Trinity Reservoir storage under Alternative 3 would generally be higher than storage under the No Action Alternative, except in wet years from April through December when Trinity Reservoir storage would be slightly lower than the No Action Alternative (Table O-247). Minor differences, less than 5%, in April–December during wet years would be unlikely to reduce the availability or suitability of larval and juvenile rearing and emigration Trinity Reservoir fish species. There would be increases in reservoir storage of greater than 5% under Alternative 3 compared with the No Action Alternative in below normal years from July through December; in dry years from August through November; and critically dry years from April through January. These increases in Trinity Reservoir storage between Alternative 3 and the No Action Alternative are not likely to have a detectable influence on the water temperature and habitat suitability for larval and juvenile rearing and emigration of Trinity Reservoir fish species.

Adult Holding

The life expectancy of rainbow trout can be four to eight years in northern California lake populations. After maturing, resident rainbow trout will migrate upstream to spawn in tributaries. They can spawn annually and will quickly move back downstream to the reservoir or lake (Moyle 2002), moving to cooler, deeper waters during the summer months (Belica 2007). Brown trout typically become sexually mature at age 2 or 3 and have been found as old as can live for up to 9 years in California, spawning several times during their life (Moyle 2002, Belica 2007). Brown trout will use varying habitats within the reservoir and will also move to cooler waters in the summer habitats (Belica 2007).

Warmwater species will remain in the reservoir their entire lives. Smallmouth bass prefer narrow bays and upstream ends of reservoirs or along the shore where rocky shelves are present at a depth of 1–10m (Moyle 2002). They become sexually mature at age three to four and typically live less than 7 years (USFWS 1983, Habitat Suitability Information: Smallmouth Bass, FWS/OBS-82/10.36). Age of largemouth bass in California reservoirs is four to five years and they typically spawn during their second season (Moyle 2002). Adult bass tend to prefer deeper, colder waters in lakes and reservoirs in areas with vegetation and other forms of cover (USFWS 1983, Habitat Suitability Information: Largemouth Bass, FWS/OBS-82/10.16). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002). They become sexually mature at age 3 and will spawn multiple times during their lifetime of up to eight to 10 years (Moyle 2002).

The effects analysis period for both coldwater and warmwater fish species adult holding is January through December.

Potential Changes to Trinity Reservoir Fish Species from Seasonal Operations

Trinity Reservoir storage under Alternative 3 would generally be higher than storage under the No Action Alternative, except in wet years from April through December when Trinity Reservoir storage would be slightly lower than the No Action Alternative (Table O-247). Minor differences, less than 5%, in April–December during wet years would be unlikely to reduce the availability or suitability for adult holding habitat of Trinity Reservoir fish species. There would be increases in reservoir storage of greater than 5% under Alternative 3 compared with the No Action Alternative in below normal years from July through December; in dry years from August through November; and critically dry years from April through January. These increases in Trinity Reservoir storage between Alternative 3 and the No Action Alternative are unlikely to have a detectable influence on the water temperature and habitat suitability for adult holding habitat of Trinity Reservoir fish species.

O.6.34 Central Valley Reservoir Species

O.6.34.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations

Shasta Reservoir

Warmwater Species

Reductions in Shasta Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-165.

For Alternative 3, there would be the same or up to 16 fewer WSE reductions of 6 feet or more compared to the No Action Alternative. These results indicate that Alternative 3 would have a beneficial effect on warmwater species in Shasta Reservoir.

Coldwater Species

Shasta Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-166.

For Alternative 3, storage would be similar to or greater than storage under the No Action Alternative. This indicates that Alternative 3 would have beneficial effects to coldwater reservoir species in Shasta Reservoir.

Whiskeytown Reservoir

Warmwater Species

Reductions in Whiskeytown Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-167.

For Alternative 3, there would be no or negligible difference in WSE month-over-month reductions of 6 feet or more relative to the No Action Alternative. Therefore, there would be no effect or negligible effects of Alternative 3 on warmwater species in Whiskeytown Reservoir.

Coldwater Species

Whiskeytown Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-168.

End-of-month storage volume under Alternative 3 would be similar to that of the No Action Alternative. These results indicate that Alternative 3 would have negligible effects on coldwater species in Whiskeytown Reservoir.

Folsom Reservoir

Warmwater Species

Reductions in Folsom Reservoir WSE month-over-month reductions of six feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O=169.

There would be zero to 20 fewer reductions of six feet or more under Alternative 2 than the No Action Alternative depending on month. These results indicate that there would be a beneficial effect of Alternative 3 on warmwater species in Folsom Reservoir.

Coldwater Species

Folsom Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-170.

For Alternative 3, there would be negligible difference in storage volume compared to the No Action Alternative in wet water years. In the other water years, storage volume under Alternative 3 would be 11.1% lower to 10.4% higher than storage volume under the No Action Alternative. These results indicate that there would be both beneficial and negative effects of Alternative 3 on coldwater species in Folsom Reservoir.

New Melones Reservoir

Warmwater Species

Reductions in New Melones Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Melones 2.

For Alternative 3, there would be zero to six fewer WSE month-over-month reductions of six feet or more than the No Action Alternative depending on month. These results indicate that there would be a beneficial effect of Alternative 3 on warmwater species in New Melones Reservoir.

Coldwater Species

New Melones Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table O-172.

For Alternative 3, there would be negligible differences in storage volume throughout the period analyzed compared to the No Action Alternative. This indicates that Alternative 3 would have negligible effects on coldwater species in New Melones Reservoir.

O.6.35 Delta-Mendota Canal/California Aqueduct Species

O.6.35.1 Potential Changes to Delta-Mendota Canal/California Aqueduct Species from Seasonal Operations

Water from the Delta is diverted through the California Aqueduct and Delta-Mendota Canal and held for off-stream storage (e.g., in San Luis Reservoir) and there is no coldwater habitat in the Delta-Mendota Canal. Therefore, no analysis of coldwater habitat was conducted. Warmwater species such as black basses and striped bass support recreational fishing in the California Aqueduct. Water velocity in the canal is not specifically managed to support or enhance recreational fisheries. Increases in water velocity may decrease water temperatures and flowing water for species, improving conditions; while decreases in water velocity may increase water temperatures and lead to stagnant water for species, diminishing conditions.

Differences in flows and velocity under Alternative 3, relative to the No Action Alternative, are expected to be minimal thus, impacts to species present are not expected to change.

O.6.36 San Luis Reservoir Species

O.6.36.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations

Warmwater Species

Reductions in San Luis Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects. Please see Section O.4.33.2, *Methods,* for details on the methods used in this analysis. Results are presented in Table O-173.

For Alternative 3, there would be 11 fewer to 22 more WSE month-over-month reductions of six feet or more than under the No Action Alternative depending on month. These results indicate that there would be predominantly negative effects of Alternative 3 on warmwater species in San Luis Reservoir with some beneficial effects.

O.6.37 Southern Resident Killer Whale

O.6.37.1 Nearshore Pacific Ocean on the California Coast

Changes in water operations under the alternatives could have the potential to affect Chinook salmon prey for Southern Resident Killer Whale (Southern Resident) relative to the No Action Alternative. Outlined below are expected changes in Southern Resident prey. Four lines of evidence were used (Salmort, XT, CVPIA SIT LCM, and DPM), and Attachment F.7, *Change in Abundance Estimate of Central Vally Chinook Salmon Available to Southern Resident Killer Whales*, provides detailed results of all models and analyses.

Based on the lines of evidence, Alternative 3 is predicted to have an annual abundance of about 233,449 Chinook salmon that survive to adulthood or about 3,505,241 pounds of Chinook salmon biomass in the ocean available as potential prey to Southern Residents. This is about 699 more Chinook salmon or 10,495 pounds more than the No Action Alternative. The modeling results suggest Alternative 3 would benefit Southern Residents relative to the No Action Alternative.

O.7 Alternative 4

Alternative 4 provides alternative criteria for Shasta Reservoir and incorporates improved real-time analytics for using real-time information to support water deliveries in the Delta while limiting effects on listed species.

O.7.1 Trinity River

O.7.1.1 Trinity River Flows below Lewiston Dam

CalSim 3 modeling suggests that average flow released at Lewiston Dam under Alternative 4 would generally be higher than or similar to flow under the No Action Alternative (Table O-264) with substantial increases (greater than 5%) in wet years in December and January and above normal years in February. Table O-264 shows that the highest flows under both alternatives are expected primarily in May and June of all water year types and during winter, spring, and early summer of wet water years and January through March and May through July of above normal water years. Throughout the full simulation period, flows on average are slightly higher under Alternative 4 December through March.

O.7.1.2 Trinity Reservoir storage

CalSim 3 modeling suggests that average monthly Trinity Reservoir storage under Alternative 4 would generally be higher than storage under the No Action Alternative (Table O-265). Table O-265 shows that there are no increases or decreases in storage greater than 5% throughout the year under Alternative 4 compared with the No Action Alternative. Throughout the full simulation period, Trinity Reservoir storage on average is slightly higher under Alternative 4 than the No Action Alternative across all months.

Table O-264. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Trinity River below Lewiston Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	373	393	1,133	1,872	1,843	2,002	1,035	4,637	3,054	1,122	760	760
Above Normal (14%)	373	403	785	1,016	1,194	1,021	552	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	931	300	606	427	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	342	720	840	912	900	682	3,598	1,820	814	834	834
ALTERNATIVE 4												
Wet (28%)	373	393	1,193	1,985	1,804	2,070	1,034	4,637	3,054	1,122	760	760
Above Normal (14%)	373	398	788	1,024	1,393	1,024	551	4,433	2,286	1,055	863	863
Below Normal (18%)	373	300	901	300	606	447	524	3,357	1,400	740	863	863
Dry (24%)	373	300	300	300	300	300	538	3,009	1,062	586	863	863
Critically Dry (16%)	373	300	300	300	300	300	571	2,201	867	491	863	863
Full Simulation Period Average	373	341	731	873	929	924	681	3,598	1,820	814	834	834
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	0	0	60	114	-38	68	-1	0	0	0	0	0
Above Normal (14%)	0	-5	3	9	199	4	-1	0	0	0	0	0
Below Normal (18%)	0	0	-31	0	0	20	0	0	0	0	0	0
Dry (24%)	0	0	0	0	0	0	0	0	0	0	0	0
Critically Dry (16%)	0	0	0	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	0	-1	12	33	17	23	0	0	0	0	0	0

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-265. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Trinity Reservoir storage for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,656	1,658	1,709	1,764	1,945	2,061	2,239	2,194	2,105	2,008	1,879	1,745
Above Normal (14%)	1,496	1,518	1,581	1,661	1,837	2,005	2,165	2,079	1,992	1,880	1,702	1,546
Below Normal (18%)	1,263	1,295	1,392	1,536	1,640	1,773	1,900	1,817	1,740	1,602	1,432	1,298
Dry (24%)	1,060	1,100	1,244	1,385	1,492	1,619	1,706	1,606	1,513	1,364	1,199	1,088
Critically Dry (16%)	727	737	810	1,004	1,051	1,123	1,140	1,064	995	927	822	753
Full Simulation Period Average	1,279	1,299	1,386	1,496	1,623	1,745	1,864	1,788	1,704	1,589	1,442	1,320
ALTERNATIVE 4												
Wet (28%)	1,681	1,674	1,720	1,767	1,951	2,062	2,239	2,194	2,107	2,008	1,880	1,759
Above Normal (14%)	1,527	1,548	1,608	1,683	1,847	2,015	2,176	2,090	2,005	1,891	1,716	1,577
Below Normal (18%)	1,272	1,301	1,396	1,555	1,659	1,791	1,918	1,835	1,761	1,627	1,446	1,311
Dry (24%)	1,083	1,122	1,266	1,391	1,502	1,628	1,715	1,615	1,524	1,386	1,225	1,113
Critically Dry (16%)	743	754	826	1,008	1,049	1,110	1,142	1,066	999	928	842	768
Full Simulation Period Average	1,300	1,317	1,402	1,506	1,632	1,750	1,871	1,795	1,713	1,601	1,456	1,339
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	24	16	10	3	5	1	0	0	2	0	1	13
Above Normal (14%)	31	29	27	22	11	11	11	11	13	10	14	31
Below Normal (18%)	9	6	4	20	20	18	17	18	21	25	14	13
Dry (24%)	23	23	21	7	10	10	8	10	11	22	26	24
Critically Dry (16%)	16	16	16	4	-1	-13	1	1	4	1	20	16
Full Simulation Period Average	21	18	15	10	9	5	7	7	9	12	14	19

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.7.2 Sacramento River

Alternative 4 provides alternative criteria for Shasta Reservoir and incorporates improved real-time analytics for using real-time information to support water deliveries in the Delta while limiting effects on listed species. On the Sacramento River, Reclamation would make releases from Shasta Reservoir for flood control, minimum instream flows, senior water rights, Delta requirements, and deliveries to CVP water service contractors.

Reclamation would manage planned releases from Shasta Reservoir for water service contract deliveries to achieve an EOS storage of 2.0 MAF in Shasta Reservoir based on the 90% forecast unless a less conservative forecast requires more releases. To address early season hydrologic uncertainty, Reclamation would limit the use of water under North of Delta Agricultural water service contractor allocations to no more than 30 TAF prior to the temperature management season and completion of a TMP. If reductions to water service contracts would not achieve 2.0 MAF of storage in Shasta Reservoir by EOS, Reclamation would reduce releases for the Project Water component of the SRS Contractors' Contracts, resulting in diversions of ~60% of contract totals. Alternative 4 includes drought toolkit action such as Wilkins Slough Relief and relaxation of D-1641 water quality requirements that may improve the volume of coldwater pool and level of drought protection in Shasta Reservoir.

Reclamation would coordinate through governance to implement a water temperature management strategy that considers EOS Coldwater Pool and minimization of modeled Temperature Dependent Mortality. The water temperature management strategy would start with a 53.5°F temperature target at or downstream of CCR from May 15 through October 30 while preserving a projected EOS coldwater pool of 400 TAF. If projections show EOS coldwater pool cannot be achieved, the water temperature management strategy would relax water temperatures in the following order: target ≤56°F at CCR starting May 15 and delay the ≤53.5°F target to no later than June 15; target June 16 temperatures ≤54°F at CCR through October 30; relax end-of-October temperatures to ≤56°F daily to as early as October 1 and reduce the EOS coldwater pool target to 200 TAF; increase June 16 through September 30 temperatures to ≤56°F; reduce the EOS coldwater pool target and confer on additional drought toolkit actions that prepare a TMP consistent with requirements in WRO 90-5 and update the plan throughout the water temperature management season to improve water temperature conditions on or after June 16.

December through February default releases at Keswick Dam would be determined by the Shasta Reservoir EOS Storage level. If storage is less than 2.4 MAF, then releases would be at 3,250 cfs. If storage is greater than or at 2.4 MAF, then releases would be at 4,000 cfs. If storage is greater than or at 2.8 MAF, then releases would be at 4,500 cfs. If storage is greater than or at 3.2 MAF, then releases would be at 5,000 cfs.

O.7.2.1 Sacramento River Flows below Keswick Dam

Under Alternative 4 compared to the No Action Alternative, CalSim 3 modeling suggests that average monthly flows below Keswick Dam are similar (less than a 5% difference) throughout the full simulation period apart from December and September, which see a flow increase and decrease, respectively (Table O-266). The largest decreases under Alternative 4 compared to the No Action Alternative are expected in February and May through August of critically dry water years, with the largest decrease in May (11%). The largest increases under Alternative 4

compared to the No Action Alternative are expected in October (10%) and November (18%) of critically dry water years.

O.7.2.2 Sacramento River Flows below Red Bluff Diversion Dam

Under Alternative 4 compared to the No Action Alternative, CalSim 3 modeling suggests that average monthly flows below Red Bluff Diversion Dam are similar throughout the full simulation period, with the exception of September (Table O-267). Decreases under Alternative 4 compared to the No Action Alternative are expected in May through August of critically dry water years, with the largest decrease expected in June and July (11%). Increases under Alternative 4 compared to the No Action Alternative are expected in October (9%) and November (15%) of critically dry water years and November (7%) of below normal water years.

O.7.2.3 Sacramento River Flows at Wilkins Slough

Under Alternative 4 compared to the No Action Alternative, CalSim 3 modeling suggests that average monthly flows at Wilkins Slough are similar throughout the full simulation period except for September (Table O-268). The largest decreases in flow under Alternative 4 are expected in June and July of critically dry water years (7%). The largest increases in flow under Alternative 4 are expected in October, November, and April of critically dry water years (15%, 19%, and 9%, respectively).

O.7.2.4 Sacramento River Flows at Hamilton City

Under Alternative 4 compared to the No Action Alternative, CalSim 3 modeling suggests that average monthly flows at Hamilton City are similar throughout the full simulation period except for September (Table O-269). Decreases under Alternative 4 compared to the No Action Alternative are expected in July and August of critically dry water years, with the largest decreases in July (8%). The largest increases in flow under Alternative 4 are expected in October, November, and April of critically dry water years (11%, 14%, and 7%, respectively).

Table O-266. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Keswick Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,453	6,575	8,760	17,717	23,928	15,969	9,265	7,358	8,719	13,608	10,371	9,177
Above Normal (14%)	6,557	7,216	5,406	10,012	16,075	9,999	5,427	7,925	10,098	15,553	11,005	8,571
Below Normal (18%)	5,525	5,011	7,696	4,912	5,278	5,012	5,325	9,308	10,409	14,159	10,770	5,608
Dry (24%)	4,809	5,025	7,991	3,399	4,693	4,137	5,592	8,051	10,950	13,138	9,106	5,524
Critically Dry (16%)	4,333	4,288	3,335	3,568	4,277	3,662	3,905	7,013	9,415	10,109	7,723	5,030
Full Simulation Period Average	5,869	5,675	7,067	8,633	11,711	8,352	6,279	7,899	9,863	13,307	9,804	6,909
ALTERNATIVE 4												
Wet (28%)	7,169	6,834	9,241	18,042	23,947	15,928	9,269	7,350	8,821	13,559	10,026	8,474
Above Normal (14%)	5,782	7,298	6,332	9,732	16,085	10,256	5,444	7,890	10,301	15,631	10,283	6,815
Below Normal (18%)	5,630	5,315	7,714	4,899	5,474	5,098	5,480	9,268	10,579	14,300	10,765	5,707
Dry (24%)	4,921	5,016	8,397	3,332	4,923	4,224	5,621	7,925	10,873	12,989	9,146	5,672
Critically Dry (16%)	4,735	4,994	3,427	3,604	4,314	3,488	4,022	6,392	8,780	9,213	7,046	4,939
Full Simulation Period Average	5,779	5,918	7,455	8,672	11,814	8,385	6,336	7,756	9,831	13,150	9,507	6,505
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-284	259	481	325	19	-40	4	-8	102	-49	-345	-703
Above Normal (14%)	-775	82	926	-280	10	258	17	-35	203	78	-722	-1,756
Below Normal (18%)	105	304	18	-12	196	85	154	-40	171	141	-5	100
Dry (24%)	112	-10	405	-67	229	87	29	-125	-77	-149	40	147
Critically Dry (16%)	403	706	93	36	36	-174	117	-621	-635	-896	-677	-91
Full Simulation Period Average	-90	243	388	39	103	33	57	-144	-32	-156	-297	-404

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-267. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River below Red Bluff Diversion Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,228	8,683	13,701	29,751	36,916	25,296	15,001	9,396	9,243	12,998	9,757	9,264
Above Normal (14%)	7,428	9,038	10,730	19,185	26,409	17,672	9,071	9,166	10,002	14,637	10,364	8,607
Below Normal (18%)	6,469	6,914	13,860	10,404	10,259	9,322	7,698	10,248	10,293	13,473	10,270	5,856
Dry (24%)	5,710	6,807	13,495	6,375	10,498	8,387	7,311	8,682	10,748	12,483	8,649	5,677
Critically Dry (16%)	4,793	5,342	6,988	5,988	7,268	5,869	4,836	7,539	9,555	10,051	7,595	5,321
Full Simulation Period Average	6,672	7,466	12,227	15,377	19,563	14,187	9,384	9,049	9,949	12,718	9,322	7,067
ALTERNATIVE 4												
Wet (28%)	7,909	8,961	14,253	30,158	36,859	25,326	15,033	9,455	9,248	12,906	9,378	8,542
Above Normal (14%)	6,616	9,137	11,715	18,992	26,343	18,000	9,102	9,192	10,096	14,664	9,600	6,832
Below Normal (18%)	6,537	7,246	13,944	10,476	10,402	9,477	7,865	10,261	10,339	13,543	10,204	5,926
Dry (24%)	5,792	6,817	13,965	6,389	10,743	8,531	7,337	8,624	10,559	12,265	8,629	5,789
Critically Dry (16%)	5,218	6,055	7,080	6,081	7,342	5,725	5,014	7,131	8,952	9,238	6,981	5,246
Full Simulation Period Average	6,557	7,728	12,672	15,495	19,634	14,280	9,462	8,992	9,830	12,526	8,994	6,644
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-319	278	552	407	-57	30	32	59	5	-92	-379	**-722**
Above Normal (14%)	**-812**	99	**985**	-193	-66	328	31	26	94	27	**-764**	**-1,775**
Below Normal (18%)	68	332	84	72	143	155	167	13	46	70	-66	70
Dry (24%)	82	10	470	14	245	144	26	-58	-189	-218	-20	112
Critically Dry (16%)	**425**	**713**	92	93	74	-144	178	**-408**	**-603**	**-813**	**-614**	-75
Full Simulation Period Average	-115	262	445	118	71	93	78	-57	-119	-192	-328	**-423**

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-268. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River near Wilkins Slough for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	6,747	7,468	10,397	18,705	19,917	17,996	14,436	7,416	5,607	7,544	5,925	7,204
Above Normal (14%)	5,961	7,038	9,668	15,284	18,028	16,281	11,131	6,025	5,489	8,795	6,524	6,581
Below Normal (18%)	4,873	5,672	11,096	10,852	11,463	11,209	8,152	5,869	5,299	7,459	6,026	3,788
Dry (24%)	4,113	5,375	9,640	7,139	11,119	10,068	6,993	4,676	5,632	6,501	4,502	3,592
Critically Dry (16%)	2,894	3,464	6,820	6,285	8,177	7,026	3,957	3,317	4,791	4,776	3,949	3,168
Full Simulation Period Average	5,082	5,977	9,695	12,049	14,141	12,876	9,379	5,629	5,410	7,011	5,369	4,989
ALTERNATIVE 4												
Wet (28%)	6,419	7,785	10,806	18,783	19,912	18,021	14,471	7,476	5,617	7,466	5,559	6,455
Above Normal (14%)	5,119	6,988	10,209	15,181	18,013	16,399	11,162	6,064	5,560	8,836	5,788	4,811
Below Normal (18%)	4,948	5,990	11,168	10,904	11,507	11,294	8,316	5,841	5,314	7,536	5,952	3,870
Dry (24%)	4,202	5,335	9,911	7,131	11,215	10,181	7,029	4,648	5,455	6,305	4,492	3,678
Critically Dry (16%)	3,300	4,062	6,956	6,388	8,219	6,903	4,260	3,367	4,671	4,517	3,703	3,259
Full Simulation Period Average	4,959	6,196	9,989	12,081	14,175	12,923	9,480	5,648	5,364	6,920	5,109	4,582
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-328	317	409	78	-5	25	35	60	10	-78	-366	-749
Above Normal (14%)	-842	-50	541	-103	-15	118	31	39	71	41	-736	-1,770
Below Normal (18%)	75	318	72	52	44	85	164	-28	15	77	-74	82
Dry (24%)	89	-40	271	-8	96	113	36	-28	-177	-196	-10	86
Critically Dry (16%)	406	598	136	103	42	-123	303	50	-120	-259	-246	91
Full Simulation Period Average	-123	219	294	32	34	47	101	19	-46	-91	-260	-407

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-269. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Sacramento River at Hamilton City for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,774	9,060	15,844	36,160	43,468	29,725	17,650	8,737	7,593	10,522	8,015	8,486
Above Normal (14%)	7,022	9,205	13,122	23,971	31,918	21,265	10,557	7,853	7,987	12,017	8,577	7,776
Below Normal (18%)	6,086	7,165	17,022	13,255	12,647	11,442	8,573	8,564	8,090	10,753	8,376	5,047
Dry (24%)	5,424	6,996	15,816	7,835	13,272	10,306	7,768	6,767	8,428	9,720	6,726	4,808
Critically Dry (16%)	4,248	5,011	8,610	7,004	8,624	6,911	4,760	5,640	7,496	7,846	6,133	4,536
Full Simulation Period Average	6,264	7,638	14,556	18,868	23,481	16,939	10,589	7,614	7,923	10,152	7,548	6,253
ALTERNATIVE 4												
Wet (28%)	7,454	9,338	16,398	36,567	43,415	29,758	17,685	8,799	7,600	10,433	7,639	7,761
Above Normal (14%)	6,205	9,302	14,103	23,782	31,856	21,592	10,589	7,882	8,080	12,045	7,816	6,001
Below Normal (18%)	6,156	7,497	17,108	13,327	12,792	11,599	8,748	8,580	8,135	10,823	8,309	5,118
Dry (24%)	5,507	7,006	16,284	7,847	13,516	10,449	7,795	6,711	8,242	9,505	6,710	4,918
Critically Dry (16%)	4,683	5,670	8,713	7,098	8,699	6,775	5,039	5,521	7,182	7,341	5,748	4,589
Full Simulation Period Average	6,150	7,891	15,001	18,986	23,554	17,035	10,686	7,606	7,851	10,012	7,259	5,849
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-320	278	554	407	-53	33	35	62	7	-89	-376	-725
Above Normal (14%)	-817	97	981	-189	-62	327	32	29	93	28	-761	-1,775
Below Normal (18%)	70	332	86	72	145	157	175	16	45	70	-67	71
Dry (24%)	83	10	468	12	244	143	27	-56	-186	-215	-16	110
Critically Dry (16%)	435	659	103	94	75	-136	279	-119	-314	-505	-385	53
Full Simulation Period Average	-114	253	445	118	73	96	97	-8	-72	-140	-289	-404

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.7.3 Bay-Delta

O.7.3.1 Delta Exports

Alternative 4 provides alternative criteria for Shasta Reservoir and incorporates improved real-time analytics for using real-time information to support water deliveries in the Delta while limiting effects on listed species. Reclamation and DWR will operate to the Hutton (2008) OMR index to allow for operational planning and real-time adjustments. Reclamation and DWR will reduce exports to achieve certain OMR thresholds when one or more of the following conditions listed in Chapter 3 Alternatives Section 3.6.4.2.1 to 3.6.4.4. Other alterations to operations are the same as Alternative 2.

O.7.3.2 Delta X2

CalSim 3 modeling suggests that the estimated X2 position under Alternative 4 when compared to the No Action Alternative, does not greatly change (Table O-270). Table O-270 suggests that most landward X2 positions are expected during late summer to fall months in the critically dry years and the most seaward positions are expected during the winter to early spring months in wet years for both alternatives. The largest changes in X2 position under Alternative 4 as compared to the No Action Alternative are expected in September and October of wet and above normal years. For the full simulation period, when comparing Alternative 4 to the No Action Alternative, X2 position did not change.

O.7.3.3 Delta Exports

CalSim 3 modeling suggests that the total exports of the SWP and CVP under Alternative 4 when compared to the No Action Alternative increased from February to May across most water year types. Exports only decreased in June and December for most of the water year types (Table O-271). Table O-271 suggests that exports were generally highest in August for both alternatives. Exports were generally the lowest in summer during the critically dry water year type for both alternatives. For the full simulation period, total exports when compared to the No Action Alternative increased from February–May and decreased in June and December.

O.7.3.4 Delta Outflow

Under Alternative 4 when compared to the No Action Alternative, Delta outflow generally decreased in May and July for the wet and above normal water years. Outflow increased in June in above normal water year types, in June for the below normal water year type and in December in wet, above normal, and critically dry water year types (Table O-272). Table O-272 suggests total Delta outflow is highest in February during wet years and lowest in the late summer–fall during the critically dry water year type for both alternatives. For the full simulation period when compared to the No Action Alternative, total Delta outflow decreases in May and August through October and increases in December.

O.7.3.5 Delta OMR

CalSim 3 modeling suggests that Old and Middle River (OMR) combined flows under Alternative 4 when compared to the No Action Alternative is generally more negative across all water year types from February–May and generally less negative across most water year types from December–January and June (Table O-273). Table O-273 suggests that OMR flows were generally the most negative in August of below normal years for both alternatives, and the least negative in April during critically dry years for both alternatives. For the full simulation period, OMR flows were more negative from February–May and less negative from December and June.

O.7.3.6 Sacramento River at Rio Vista

CalSim 3 modeling suggests that average flows in the Sacramento River at Rio Vista under Alternative 4 compared to the No Action Alternative are similar (less than 5% difference) with the exception of September (Table O-274). The greatest reductions are expected August through October of wet and above normal water year type under Alternative 4 compared to the No Action Alternative. The greatest increase is expected during April of critically dry water year types under Alternative 4 compared to the No Action Alternative.

Table O-270. CalSim 3 estimated X2 Position by Water Year Type and Month for the No Action Alternative, Alternative 4 and Differences between Them

Alternative	X2 Position (km)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	79	80	74	56	54	55	58	63	72	78	83	79
Above Normal (14%)	80	83	77	62	57	57	62	69	77	80	83	80
Below Normal (18%)	90	89	74	70	66	64	68	72	80	83	87	90
Dry (24%)	91	88	78	79	69	68	72	77	82	86	89	92
Critically Dry (16%)	94	93	85	82	77	77	83	87	89	92	93	93
Full Simulation Period Average	86	86	77	69	64	64	68	73	79	83	87	86
ALTERNATIVE 4												
Wet (28%)	83	82	73	56	54	55	58	64	72	79	84	84
Above Normal (14%)	85	86	76	61	57	57	63	70	77	80	85	85
Below Normal (18%)	90	89	74	69	66	64	68	74	80	83	86	90
Dry (24%)	91	88	78	79	69	68	72	78	82	86	89	92
Critically Dry (16%)	94	93	85	82	77	78	82	87	89	92	93	93
Full Simulation Period Average	88	87	76	69	64	64	68	73	79	83	87	88
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	4	2	-1	0	0	0	0	1	0	0	2	**5**
Above Normal (14%)	5	2	-1	-1	0	0	1	1	0	0	2	**5**
Below Normal (18%)	0	0	0	-1	0	0	0	2	0	0	0	0
Dry (24%)	0	0	0	0	0	0	0	1	0	0	0	0
Critically Dry (16%)	0	0	-1	0	0	0	0	0	0	0	0	0
Full Simulation Period Average	2	1	-1	0	0	0	0	1	0	0	1	2

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses.

Table O-271. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Total Exports of SWP and CVP for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	7,586	10,782	8,504	9,217	9,986	8,557	7,132	6,750	7,386	10,597	10,891	8,364
Above Normal (14%)	5,987	10,099	8,039	7,441	8,282	6,935	4,259	4,336	5,864	10,356	10,686	5,703
Below Normal (18%)	5,887	7,526	7,027	6,408	7,112	6,214	3,808	3,669	5,502	9,913	8,767	6,714
Dry (24%)	4,225	6,067	5,475	6,216	6,321	5,760	3,082	2,916	4,929	7,138	4,116	5,320
Critically Dry (16%)	2,715	2,579	5,724	5,078	5,559	4,421	2,045	2,124	1,895	1,631	1,637	2,660
Full Simulation Period Average	5,503	7,732	7,024	7,080	7,642	6,575	4,345	4,197	5,365	8,175	7,373	6,051
ALTERNATIVE 4												
Wet (28%)	9,054	10,716	7,069	8,848	10,536	9,681	8,098	8,505	7,213	10,564	11,318	9,023
Above Normal (14%)	6,791	10,166	6,931	7,070	9,167	7,405	5,819	5,710	5,422	10,864	11,471	6,955
Below Normal (18%)	5,850	7,626	6,603	6,264	7,572	6,218	4,812	4,691	5,031	10,457	9,410	7,040
Dry (24%)	4,240	5,990	5,121	6,265	6,780	5,713	3,580	3,540	4,391	7,252	4,285	5,361
Critically Dry (16%)	2,854	2,936	5,183	5,043	6,198	4,312	2,272	2,323	1,813	1,538	1,444	2,793
Full Simulation Period Average	6,053	7,776	6,214	6,905	8,215	6,928	5,171	5,246	5,028	8,347	7,728	6,501
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	1,467	-66	-1,435	-369	550	1,124	966	1,755	-173	-33	427	659
Above Normal (14%)	804	67	-1,108	-371	886	470	1,560	1,374	-441	509	785	1,252
Below Normal (18%)	-37	100	-424	-145	460	5	1,003	1,021	-472	544	643	326
Dry (24%)	16	-77	-353	49	459	-47	498	624	-538	114	169	41
Critically Dry (16%)	139	357	-541	-35	639	-109	227	199	-81	-93	-192	133
Full Simulation Period Average	549	45	-810	-175	573	353	825	1,049	-337	172	355	450

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-272. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Delta Outflow (Total) for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,918	12,055	30,736	96,898	122,709	90,897	54,587	31,188	13,556	9,410	6,009	11,294
Above Normal (14%)	8,664	7,873	21,249	53,164	71,004	58,493	27,859	17,453	9,163	10,682	6,287	10,956
Below Normal (18%)	5,366	6,747	30,789	25,764	29,373	26,423	19,249	15,376	7,772	8,121	4,144	3,679
Dry (24%)	5,887	9,013	30,407	13,571	27,568	19,839	14,134	10,846	7,191	5,232	3,826	3,213
Critically Dry (16%)	3,094	5,758	11,444	10,903	15,095	10,560	6,745	5,961	4,141	3,217	3,030	3,554
Full Simulation Period Average	6,640	8,798	26,350	44,213	58,618	44,847	27,121	17,500	8,866	7,363	4,712	6,698
ALTERNATIVE 4												
Wet (28%)	6,694	12,471	33,121	98,366	122,354	89,862	53,592	29,510	13,866	9,090	4,344	7,816
Above Normal (14%)	6,685	8,164	23,380	53,962	70,408	58,636	25,834	16,119	9,641	9,785	4,029	7,461
Below Normal (18%)	5,457	6,883	31,370	26,149	30,075	27,116	18,485	13,879	8,241	7,782	4,206	3,615
Dry (24%)	5,849	9,140	31,553	13,475	27,717	19,912	13,785	10,300	7,219	5,014	3,531	3,235
Critically Dry (16%)	3,099	5,898	12,288	11,246	14,494	10,309	6,940	5,866	4,300	3,334	3,030	3,458
Full Simulation Period Average	5,728	9,033	27,843	44,837	58,501	44,680	26,369	16,428	9,136	7,052	3,870	5,213
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-2,224	416	2,385	1,468	-355	-1,035	-995	-1,678	310	-320	-1,665	-3,478
Above Normal (14%)	-1,979	291	2,131	799	-596	143	-2,026	-1,334	478	-897	-2,258	-3,495
Below Normal (18%)	90	136	581	385	702	692	-763	-1,497	470	-339	62	-64
Dry (24%)	-38	126	1,147	-96	149	73	-349	-545	28	-219	-295	22
Critically Dry (16%)	4	140	844	343	-601	-251	195	-95	159	116	0	-96
Full Simulation Period Average	-912	236	1,494	624	-117	-168	-752	-1,072	270	-310	-842	-1,485

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-273. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Old and Middle River Combined Flow for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	-6,128	-8,400	-5,569	-2,718	-1,706	-1,261	-1,861	-1,095	-4,159	-9,708	-10,116	-7,642
Above Normal (14%)	-4,935	-8,399	-5,963	-4,302	-3,528	-3,169	-1,650	-2,348	-4,778	-10,023	-10,386	-5,854
Below Normal (18%)	-5,152	-6,123	-4,900	-4,312	-4,100	-3,658	-2,060	-2,114	-4,859	-9,847	-9,043	-6,759
Dry (24%)	-3,644	-4,859	-3,704	-4,442	-4,031	-3,933	-2,095	-2,204	-4,796	-8,003	-4,819	-5,490
Critically Dry (16%)	-2,539	-1,982	-4,330	-3,630	-3,692	-3,053	-1,079	-1,748	-2,272	-2,668	-2,463	-3,002
Full Simulation Period Average	-4,639	-6,178	-4,875	-3,786	-3,268	-2,888	-1,798	-1,825	-4,222	-8,241	-7,465	-5,974
ALTERNATIVE 4												
Wet (28%)	-7,624	-8,358	-4,235	-2,371	-2,203	-2,296	-2,774	-2,704	-4,032	-9,691	-10,572	-8,422
Above Normal (14%)	-5,782	-8,502	-4,938	-4,022	-4,387	-3,592	-3,545	-3,602	-4,381	-10,469	-11,170	-7,058
Below Normal (18%)	-5,161	-6,212	-4,487	-4,167	-4,487	-3,654	-3,019	-3,090	-4,438	-10,331	-9,532	-6,988
Dry (24%)	-3,658	-4,794	-3,359	-4,488	-4,432	-3,877	-2,588	-2,816	-4,304	-8,073	-4,985	-5,514
Critically Dry (16%)	-2,594	-2,311	-3,826	-3,609	-4,273	-2,946	-1,262	-1,936	-2,150	-2,556	-2,249	-3,108
Full Simulation Period Average	-5,198	-6,231	-4,114	-3,632	-3,786	-3,206	-2,640	-2,803	-3,918	-8,385	-7,796	-6,425
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1,496	43	1,334	347	-497	-1,036	-913	-1,609	127	17	-457	-780
Above Normal (14%)	-847	-103	1,025	280	-859	-423	-1,895	-1,253	397	-446	-784	-1,204
Below Normal (18%)	-9	-89	413	145	-387	4	-959	-976	421	-484	-489	-230
Dry (24%)	-14	66	346	-45	-401	56	-493	-611	492	-71	-166	-24
Critically Dry (16%)	-55	-329	504	21	-581	107	-183	-188	122	112	214	-106
Full Simulation Period Average	-559	-53	760	155	-518	-318	-841	-978	304	-144	-331	-451

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-274. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Sacramento River at Rio Vista Flow for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	8,929	13,097	29,134	82,363	104,439	73,383	40,479	20,772	9,466	11,109	9,638	11,382
Above Normal (14%)	7,795	10,558	22,225	47,116	62,080	48,912	20,595	13,844	7,846	13,276	10,441	10,213
Below Normal (18%)	6,147	8,224	29,745	23,742	25,296	22,329	14,058	12,234	7,154	11,407	8,272	6,178
Dry (24%)	6,377	9,250	27,844	13,212	25,067	17,799	11,076	9,263	7,324	8,513	5,224	5,046
Critically Dry (16%)	3,621	4,344	12,645	10,561	13,992	9,893	4,748	5,310	3,824	3,870	3,391	3,869
Full Simulation Period Average	6,849	9,603	25,425	38,792	50,742	37,269	20,166	13,029	7,406	9,685	7,446	7,559
ALTERNATIVE 4												
Wet (28%)	8,429	13,494	29,965	83,377	104,601	73,447	40,498	20,860	9,600	10,890	8,805	9,580
Above Normal (14%)	6,905	10,909	23,206	47,661	62,394	49,462	20,647	13,898	7,884	12,990	9,484	8,701
Below Normal (18%)	6,203	8,474	29,853	23,919	26,291	22,911	14,334	11,912	7,178	11,536	8,644	6,276
Dry (24%)	6,280	9,409	28,554	13,178	25,642	17,801	11,252	9,383	6,980	8,422	5,139	5,079
Critically Dry (16%)	3,759	4,542	12,884	10,831	13,990	9,568	5,079	5,402	3,830	3,829	3,204	3,859
Full Simulation Period Average	6,583	9,880	26,030	39,219	51,148	37,417	20,324	13,047	7,371	9,578	7,095	6,866
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-500	397	831	1,014	162	64	20	88	133	-219	-833	-1,803
Above Normal (14%)	-891	351	981	545	314	550	52	54	38	-286	-957	-1,512
Below Normal (18%)	56	250	108	177	995	582	277	-322	24	129	372	97
Dry (24%)	-97	159	710	-34	576	3	176	119	-345	-91	-85	33
Critically Dry (16%)	137	198	239	270	-2	-325	331	92	7	-41	-187	-10
Full Simulation Period Average	-266	277	606	427	406	148	158	18	-35	-106	-351	-693

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.7.4 Clear Creek

Alternative 4 provides alternative criteria for Shasta Reservoir and incorporates improved real-time analytics for using real-time information to support water deliveries in the Delta while limiting effects on listed species. Reclamation would release water through Whiskeytown Dam to provide intra-annual variation to emulate natural processes. As provided in Figure 3.4-1 and Table 3.4-2 (Chapter 3 Alternatives), flows would oscillate over a one-year period, with releases transitioning from 300 cfs in the winter, down to 100 cfs in the summer, and back to 300 cfs by the following winter. Reclamation, through the Clear Creek Technical Team, may modify the timing and flow rates provided in Figure 3.4-1 and Table 3.4-2 by February 1 and update through May on a case-by-case basis; the flow schedule is subject to agreement by Redding Electric Utility for use of their facilities.

Reclamation would release up to 10,000 acre-feet from Whiskeytown Dam for channel maintenance, spring attraction flows, and to meet other physical and biological objectives, except in years with significant uncontrolled flow. In critical years, Reclamation would release up to 5,000 acre-feet. Reclamation, through the Clear Creek Technical Team, would develop pulse flow schedules, which include measures (e.g., nighttime down ramping, slow down ramping rates, coordination with natural precipitation events) to mitigate for potential risks (e.g., potential juvenile fish stranding). Due to unknowns in winter precipitation, Clear Creek pulse flows are not to occur prior to the February SVI reporting. The full pulse flow volume (10,000 acre-feet) will be available if the SVI is greater than 5.4, at the SVI updates (i.e., dry or wetter years). If the SVI updates are equal to or less than 5.4 (critical years), Reclamation would limit releases of pulse(s) flows to 5,000 acre-feet. Reclamation would also target Whiskeytown Dam releases at 61°F from June 1 through August 15, 60°F from August 16 through September 15, and 56°F from September 16 through November 15 to not exceed the mean daily temperatures at Igo gauge. In dry, critical, or import curtailment years, Reclamation may not be able to meet these water temperatures and will operate Whiskeytown Dam as close to these water temperatures as practicable within the constraints of minimum instream flows.

O.7.4.1 Clear Creek below Whiskeytown Dam

CalSim 3 modeling under Alternative 4 compared to the No Action Alternative suggests average monthly flows below Whiskeytown Dam will generally increase November through January and March through May, and generally decrease in February and June through October (Table O-275). The largest decreases under Alternative 4 compared to the No Action Alternative are expected June through August. The largest increases under Alternative 4 compared to the No Action Alternative are expected in January or May, depending on the water year type.

Table O-275. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for Clear Creek below Whiskeytown Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	200	200	200	305	494	300	200	200	318	150	150	150
Above Normal (14%)	200	200	200	193	365	200	200	200	318	150	150	150
Below Normal (18%)	200	190	192	194	339	200	200	200	318	150	150	142
Dry (24%)	200	200	200	194	232	192	196	200	318	150	150	150
Critically Dry (16%)	117	100	143	177	169	166	153	150	225	145	141	137
Full Simulation Period Average	187	183	190	222	333	221	192	192	303	149	149	146
ALTERNATIVE 4												
Wet (28%)	168	222	270	390	414	369	235	266	221	106	114	135
Above Normal (14%)	168	222	270	275	286	271	235	266	221	106	114	135
Below Normal (18%)	168	221	258	278	286	271	235	266	221	106	114	127
Dry (24%)	168	222	270	277	252	251	228	266	221	106	114	135
Critically Dry (16%)	134	122	141	231	206	188	155	231	143	141	131	131
Full Simulation Period Average	163	207	248	301	301	280	220	261	208	112	117	133
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-32	22	70	85	-80	69	35	66	-97	-44	-36	-15
Above Normal (14%)	-32	22	70	82	-79	71	35	66	-97	-44	-36	-15
Below Normal (18%)	-32	31	66	84	-53	71	35	66	-97	-44	-36	-15
Dry (24%)	-32	22	70	83	20	59	32	66	-97	-44	-36	-15
Critically Dry (16%)	17	22	-2	54	37	22	2	81	-82	-4	-10	-6
Full Simulation Period Average	-24	24	58	79	-32	60	29	69	-95	-37	-32	-13

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.7.5 Lower American River

Alternative 4 provides alternative criteria for Shasta Reservoir and incorporates improved real-time analytics for using real-time information to support water deliveries in the Delta while limiting effects on listed species; Reclamation would seek to develop and operate under a new ATSP, otherwise operations on the lower American River are the same as the No Action Alternative.

If unable to develop and operate under a new ATSP, management actions for the American River would be the same as the No Action Alternative Reclamation and would implement the minimum release requirement (MRR) proposed by the Sacramento Area Water Forum, based on the month and annual hydrology, Figure 3.2-3 and Figure 3.2-4 (EIS, Chapter 3). Reclamation will use the 90% exceedance from the Sacramento River Index in January and the American River Index in February through December to develop the MRR (with certain spills subtracted). Reclamation will implement a spring pulse in years that the MRR for March is between 1,000 cfs and 1,500 cfs. The peak flow of the pulse flow would be three times the March MRR, even if implemented in April or May, but no higher than 4,000 cfs and lasting two days. Reclamation, through the American River Group, will develop a pulse flow schedule and may facilitate an additional spring pulse flow event if water is made available from non-CVP sources, or if there is flexibility to shape planned releases in a more variable schedule. Reclamation, through Governance, will schedule MRR releases consistent with the implementation of redd dewatering protective adjustments to limit potential redd dewatering January through May. Table 3.2-3 (Chapter 3, *Alternatives*), with linear interpolation, shows the minimum flow for steelhead redds through May.

If unable to develop and operate under a new ATSP, Reclamation will implement the existing ATSP. Each ATSP schedule determines a monthly series of water temperature targets at the Watt Avenue bridge. Schedule 1 has a water temperature upper limit of 63°F from May through September, and 56°F in October and November. Schedules 2 through 77 each represent a change in a single month's upper temperature limit by 1.0°F. Schedule 78 has a water temperature upper limit of 72°F from May through November. The ATSP may be modified for Schedule 28 or higher when temperatures are greater than 65°F at Watt Avenue Bridge in May through September, the TMP may consider a temperature location at Hazel Avenue; any schedule when greater than 65°F at Hazel Avenue bridge for May through September, the TMP will include an evaluation of whether modified Folsom Reservoir operations could support an improved temperature schedule (e.g., an alternate release schedule over the summer); any schedule when greater than 65°F at Hazel Avenue for May through September, the TMP will include an evaluation of whether modified Folsom Reservoir operations could support an improved temperature schedule (e.g., an alternate release schedule over the summer) and evaluate a power bypass during the summer and/or fall; any schedule when temperatures are greater than 56°F at Hazel Avenue in November, the TMP will evaluate a power bypass.

O.7.5.1 Lower American River for Folsom Reservoir Storage

CalSim 3 modeling under Alternative 4 compared to the No Action Alternative suggest that at Folsom Reservoir storage monthly average volume would be similar or greater throughout the full simulation period (Table O-276). Folsom Reservoir storage is not expected to decrease by more than 5% throughout the year. Increases are expected in all months of dry and critically dry water year types, with projected storage increases for almost all water year types September through December.

O.7.5.2 Lower American River below Nimbus Dam

CalSim 3 modeling of Alternative 4 compared to the No Action Alternative suggest that monthly average flows below Nimbus Dam are mostly similar throughout the year under the full simulation period (Table O-277). The largest flow increases are expected in February of dry water year types and July of critically dry year types when compared to the No Action Alternative. The largest flow decreases are expected in August through October, and February through May of critically dry water year types when compared to the No Action Alternative. October would see flow decreases for all water year types except wet years.

O.7.5.3 Lower American River at H Street

CalSim 3 modeling of Alternative 4 compared to the No Action Alternative suggest monthly average flows below Nimbus Dam are generally similar throughout the year under the full simulation period (Table O-278). The largest flow increases are expected in February of dry water year types and July of critically dry year types when compared to the No Action Alternative. The largest flow decreases are expected August through October, and February through May of critically dry water year types when compared to the No Action Alternative.

Table O-276. CalSim 3 Monthly Average Volume (TAF) by Water Year Type and Month for Folsom Reservoir Storage for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Volume (TAF)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	621	533	532	567	567	750	890	947	923	781	693	654
Above Normal (14%)	484	447	502	557	565	745	879	932	858	633	570	518
Below Normal (18%)	454	433	485	540	560	711	836	846	790	576	502	476
Dry (24%)	436	439	470	472	518	633	716	725	657	532	471	447
Critically Dry (16%)	341	318	430	430	452	503	529	524	500	440	376	362
Full Simulation Period Average	484	447	489	516	535	675	779	806	758	609	537	507
ALTERNATIVE 4												
Wet (28%)	647	548	547	567	567	749	890	946	922	791	707	681
Above Normal (14%)	537	486	533	567	567	745	880	931	856	649	592	563
Below Normal (18%)	469	457	506	556	561	720	845	850	788	587	515	486
Dry (24%)	466	464	498	529	554	678	753	753	687	556	491	470
Critically Dry (16%)	411	388	493	467	495	561	592	591	569	494	440	430
Full Simulation Period Average	520	478	518	540	551	696	800	824	776	631	562	538
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	26	15	16	0	0	-1	0	0	-1	10	13	26
Above Normal (14%)	53	39	31	10	2	1	1	0	-2	16	22	45
Below Normal (18%)	15	24	22	16	1	8	9	4	-2	11	14	10
Dry (24%)	30	25	28	57	37	45	36	28	31	24	21	23
Critically Dry (16%)	69	70	63	37	42	59	63	68	69	54	64	68
Full Simulation Period Average	36	31	29	24	16	21	20	18	17	22	25	32

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-277. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for lower American River below Nimbus Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,870	4,067	4,854	11,628	12,283	7,659	6,803	6,359	3,663	3,631	2,804	2,514
Above Normal (14%)	1,893	2,418	3,339	6,518	7,463	4,965	3,295	3,324	3,311	4,618	2,260	2,283
Below Normal (18%)	1,578	2,012	4,112	2,926	4,355	2,781	2,822	2,947	2,778	4,557	2,449	1,750
Dry (24%)	1,227	2,276	5,167	1,667	3,197	2,077	2,172	2,492	2,598	2,910	1,968	1,529
Critically Dry (16%)	761	1,347	911	1,368	1,759	1,149	970	1,302	1,425	1,613	1,689	1,016
Full Simulation Period Average	1,500	2,612	3,977	5,314	6,317	4,022	3,551	3,583	2,841	3,440	2,285	1,868
ALTERNATIVE 4												
Wet (28%)	1,869	4,254	4,842	11,699	12,284	7,675	6,790	6,359	3,681	3,443	2,753	2,299
Above Normal (14%)	1,708	2,640	3,468	6,704	7,607	4,979	3,296	3,338	3,347	4,321	2,153	1,907
Below Normal (18%)	1,473	1,880	4,144	3,083	4,639	2,652	2,815	3,023	2,882	4,347	2,403	1,817
Dry (24%)	1,112	2,355	5,122	1,648	3,563	1,945	2,311	2,627	2,548	3,014	2,014	1,491
Critically Dry (16%)	704	1,330	1,029	1,469	1,663	884	894	1,221	1,396	1,838	1,529	945
Full Simulation Period Average	1,417	2,690	4,006	5,400	6,461	3,932	3,567	3,618	2,853	3,369	2,233	1,747
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	188	-12	71	0	16	-14	0	18	-188	-51	-215
Above Normal (14%)	-185	222	130	186	144	15	1	14	36	-298	-106	-376
Below Normal (18%)	-105	-132	32	157	284	-129	-7	76	104	-210	-46	66
Dry (24%)	-115	78	-45	-19	366	-132	139	135	-50	104	46	-39
Critically Dry (16%)	-57	-18	119	101	-96	-265	-76	-81	-30	224	-159	-70
Full Simulation Period Average	-83	78	29	86	144	-91	16	35	12	-71	-52	-121

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-278. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the lower American River at H street for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	1,769	4,000	4,824	11,646	12,307	7,643	6,758	6,245	3,516	3,454	2,635	2,367
Above Normal (14%)	1,783	2,340	3,332	6,539	7,493	4,921	3,216	3,200	3,141	4,416	2,082	2,131
Below Normal (18%)	1,467	1,936	4,092	2,902	4,314	2,732	2,736	2,811	2,598	4,344	2,260	1,613
Dry (24%)	1,131	2,200	5,124	1,625	3,176	2,012	2,077	2,351	2,416	2,705	1,777	1,388
Critically Dry (16%)	647	1,251	905	1,303	1,712	1,075	862	1,165	1,244	1,416	1,495	867
Full Simulation Period Average	1,395	2,535	3,953	5,297	6,307	3,976	3,471	3,453	2,671	3,243	2,102	1,723
ALTERNATIVE 4												
Wet (28%)	1,767	4,186	4,813	11,717	12,307	7,659	6,745	6,246	3,534	3,267	2,585	2,156
Above Normal (14%)	1,600	2,562	3,461	6,724	7,637	4,936	3,217	3,214	3,177	4,120	1,976	1,763
Below Normal (18%)	1,366	1,806	4,125	3,058	4,597	2,606	2,730	2,887	2,701	4,136	2,215	1,680
Dry (24%)	1,016	2,278	5,080	1,607	3,540	1,883	2,215	2,485	2,366	2,807	1,823	1,350
Critically Dry (16%)	583	1,228	1,021	1,405	1,618	814	788	1,085	1,213	1,637	1,337	797
Full Simulation Period Average	1,312	2,612	3,982	5,383	6,451	3,887	3,488	3,489	2,682	3,171	2,050	1,604
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	186	-11	71	1	17	-13	0	18	-187	-50	-210
Above Normal (14%)	-183	222	129	185	144	15	1	14	35	-296	-107	-368
Below Normal (18%)	-102	-130	32	156	283	-127	-6	76	103	-208	-46	67
Dry (24%)	-115	78	-44	-18	364	-130	139	134	-50	102	46	-38
Critically Dry (16%)	-64	-22	116	102	-95	-261	-74	-80	-31	220	-158	-70
Full Simulation Period Average	-83	77	29	86	143	-89	17	35	11	-71	-51	-119

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.7.6 Stanislaus River

Alternative 4 provides alternative criteria for Shasta Reservoir and incorporates improved real-time analytics for using real-time information to support water deliveries in the Delta while limiting effects on listed species. Minimum instream flows (i.e., Goodwin Dam releases) would be in accordance with the 2019 New Melones SRP as modified to increase the potential outmigration response of juvenile steelhead from Winter Instability Flows, as shown in Figure 3.4-2 (EIS, Chapter 3). The SRP includes the ability to shape monthly and seasonal flow volumes. Reclamation, through the Stanislaus Watershed Team, schedules the winter instability flow volume, including combining the additional January and February releases, in consideration of timing flows to coincide with a natural storm event which may naturally cue outmigration. Modifications would use a single pulse and increase peak releases from 400 cfs to 1,500 cfs. In addition to description of the No Action Alternative, Reclamation may release additional pulse flows in November.

O.7.6.1 Stanislaus River below Goodwin Dam

CalSim 3 modeling suggests monthly average flows below Goodwin Dam under Alternative 4 compared to the No Action Alternative are expected to increase in December, February, July, and August and decrease in April (Table O-279). The largest decreases under Alternative 4 compared to the No Action Alternative are expected in April of below normal and dry water year types, May of below normal water year types, June of wet water year types, and January of above normal water year types. The largest increases under Alternative 4 compared to the No Action Alternative are expected in February of dry and critically dry water year types and June, July and August of critically dry water year types.

O.7.6.2 Stanislaus River at Mouth

CalSim 3 modeling suggests monthly average flows at the mouth of the Stanislaus River under Alternative 4 compared to the No Action Alternative are similar nearly year-round, except August and September when flows are expected to increase (Table O-280). The largest decreases under Alternative 4 compared to the No Action Alternative are expected in May of below normal and January of above normal water year types. The largest increases under Alternative 4 compared to the No Action Alternative are expected in June through September of critically dry water year types.

Table O-279. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River below Goodwin Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	875	578	752	2,005	2,111	1,887	1,680	1,984	747	288	741	870
Above Normal (14%)	742	200	352	782	1,297	889	1,177	1,134	456	273	287	260
Below Normal (18%)	685	200	462	417	641	382	846	868	335	267	284	280
Dry (24%)	617	200	490	241	230	200	636	563	269	265	283	249
Critically Dry (16%)	591	200	200	217	219	200	529	453	262	268	283	249
All	716	306	494	838	978	802	1,025	1,078	440	273	412	430
ALTERNATIVE 4												
Wet (28%)	871	580	787	2,001	2,156	1,837	1,626	2,023	626	280	780	869
Above Normal (14%)	729	200	352	577	1,311	892	1,112	1,063	415	270	285	257
Below Normal (18%)	649	200	472	440	726	347	672	715	317	267	312	327
Dry (24%)	612	200	581	224	335	200	531	544	269	265	283	249
Critically Dry (16%)	591	200	200	200	313	200	527	453	418	419	435	249
All	705	306	527	806	1,048	782	944	1,047	422	295	452	438
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-4	2	35	-4	45	-50	-54	39	-121	-7	39	-1
Above Normal (14%)	-13	0	0	-205	14	3	-65	-72	-41	-2	-1	-4
Below Normal (18%)	-36	0	10	24	85	-35	-175	-153	-18	0	28	47
Dry (24%)	-5	0	90	-17	104	0	-105	-19	0	0	0	0
Critically Dry (16%)	0	0	0	-17	94	0	-2	0	156	151	152	0
All	-11	1	33	-32	70	-20	-81	-31	-18	22	40	8

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

Table O-280. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the Stanislaus River at Mouth for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	844	777	777	1,818	2,241	2,015	1,903	2,079	1,047	549	653	771
Above Normal (14%)	559	413	411	778	1,290	1,052	1,205	1,243	643	377	313	274
Below Normal (18%)	530	396	468	450	676	519	870	984	513	312	293	291
Dry (24%)	474	354	470	330	395	276	601	707	362	235	257	258
Critically Dry (16%)	404	303	245	290	343	210	478	550	252	135	185	191
All	590	482	513	825	1,079	905	1,079	1,191	603	340	370	399
ALTERNATIVE 4												
Wet (28%)	844	779	794	1,833	2,253	2,007	1,881	2,091	995	521	663	777
Above Normal (14%)	556	411	411	662	1,234	1,055	1,191	1,184	610	363	315	279
Below Normal (18%)	534	393	474	481	726	526	798	882	473	301	313	343
Dry (24%)	474	354	522	323	436	300	576	674	352	232	258	260
Critically Dry (16%)	430	313	250	284	380	230	488	555	316	246	309	246
All	594	483	532	815	1,100	913	1,053	1,161	584	346	397	420
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	-1	1	17	14	12	-8	-22	12	-52	-28	10	7
Above Normal (14%)	-3	-2	-1	-116	-56	3	-13	-59	-33	-14	1	6
Below Normal (18%)	4	-3	6	30	50	7	-72	-102	-40	-11	20	51
Dry (24%)	-1	0	52	-7	41	24	-25	-32	-10	-2	2	3
Critically Dry (16%)	26	10	4	-6	36	20	10	5	64	111	125	55
All	4	1	19	-9	20	8	-25	-30	-19	6	27	21

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.7.7 San Joaquin River

Alternative 4 provides alternative criteria for Shasta Reservoir and incorporates improved real-time analytics for using real-time information to support water deliveries in the Delta while limiting effects on listed species. In the San Joaquin River, Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision, which is a related action not included in this consultation. There are anticipated changes in San Joaquin River flow below the confluence with the Stanislaus River, because of changes in operations at New Melones reservoir.

O.7.7.1 San Joaquin River at Vernalis

CalSim 3 modeling suggests that monthly average flows in the San Joaquin River at Vernalis under Alternative 4 compared to No Action Alternative are similar (less than 5% difference) October through September (Table O-281). The largest increases under Alternative 4 compared to the No Action Alternative are expected in July and August of critically dry water year types (22%). There are no anticipated decreases greater than 5% difference under Alternative 4 compared to the No Action Alternative.

Table O-281. CalSim 3 Monthly Average Flow (cfs) by Water Year Type and Month for the San Joaquin River at Vernalis for No Action Alternative, Alternative 4 and Differences between Them

Alternative	Monthly Flow (cfs)											
Water Year Type	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
NO ACTION ALTERNATIVE												
Wet (28%)	2,982	2,957	4,091	9,879	13,068	12,499	12,532	11,481	7,391	3,577	2,375	2,263
Above Normal (14%)	2,222	1,876	2,549	4,210	7,063	6,332	6,587	4,709	3,201	1,899	1,412	1,367
Below Normal (18%)	1,830	1,720	2,722	2,738	4,312	4,104	4,914	3,862	2,439	1,486	1,183	1,215
Dry (24%)	1,542	1,514	2,585	1,992	2,732	2,550	2,992	2,406	1,486	963	925	1,019
Critically Dry (16%)	1,288	1,244	1,499	1,821	2,162	2,038	2,287	1,665	1,129	560	616	738
All	2,061	1,969	2,863	4,618	6,425	6,063	6,399	5,413	3,494	1,856	1,396	1,407
ALTERNATIVE 4												
Wet (28%)	2,987	2,967	4,117	9,902	13,087	12,500	12,506	11,499	7,345	3,553	2,391	2,273
Above Normal (14%)	2,229	1,875	2,551	4,096	7,011	6,343	6,585	4,666	3,183	1,906	1,432	1,396
Below Normal (18%)	1,834	1,726	2,739	2,776	4,378	4,123	4,843	3,757	2,405	1,488	1,231	1,283
Dry (24%)	1,543	1,514	2,640	1,991	2,776	2,577	2,968	2,370	1,474	958	924	1,028
Critically Dry (16%)	1,324	1,263	1,518	1,814	2,194	2,060	2,299	1,669	1,197	681	752	815
All	2,070	1,975	2,890	4,614	6,451	6,078	6,375	5,385	3,480	1,869	1,434	1,440
ALTERNATIVE 4 MINUS NO ACTION ALTERNATIVE												
Wet (28%)	6	9	26	23	19	0	-25	18	-45	-24	16	10
Above Normal (14%)	7	-1	1	-114	-52	11	-2	-43	-18	6	21	29
Below Normal (18%)	5	6	18	38	66	18	-71	-105	-34	3	49	68
Dry (24%)	1	0	55	-1	44	28	-24	-35	-12	-5	-2	8
Critically Dry (16%)	36	19	19	-8	32	23	12	5	68	121	136	77
All	9	6	27	-4	26	15	-24	-28	-13	13	37	33

Results are based on the 100-year simulation period and displayed with calendar year–year type sorting. All scenarios are simulated at the 2022 median climate change and 15 centimeter sea level rise. Water year types are as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (Water Board D-1641, 1999). The percent of years of each water year type is given in parentheses. Bold blue font indicates a greater than 5% increase in flow; bold red font indicates a greater than 5% reduction in flow.

O.7.8 Sacramento River Winter-run Chinook Salmon ESU

O.7.8.1 Sacramento River

Spawning and Egg/Alevin Incubation

Winter-run Chinook salmon adults spawn from April through August with peak spawning between May and July (Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). Fry emergence occurs up to three months after eggs are spawned, so effects of flow and water temperature on winter-run Chinook salmon eggs and alevins may occur from May through November, but primarily occur during June through October.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 4, differences in mean spawning WUA are increases across all water year types when compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 4 and the No Action Alternative is a 1.9% increase in dry water years. Under Alternative 4, there are no reductions in mean estimated spawning WUA when compared to the No Action Alternative.

The monthly median value of spawning WUA under Alternative 4 is similar to the No Action Alternative across all four spawning months. Spawning WUA median values for all the modeled alternatives are relatively similar in May, June, and August. In July, the median values of spawning WUA are lower across all alternatives when compared to the other months of spawning. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in July than in the other three months (Table O-266). This results in lower spawning WUA results because the winter-run spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 5,000 to 10,000 cfs).

The results of suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for winter-run in the upper Sacramento River may not be a limiting factor under both the No Action Alternative and Alternative 4 (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The results of the two spawning habitat analyses based on CalSim 3 simulated flows suggest that Alternative 4 may have a negligible (less than 2%) increase in estimated spawning habitat during above normal water year types when compared to the No Action Alternative, and that spawning habitat may not be a limiting factor for winter-run Chinook salmon in the mainstem upper Sacramento River.

SIT Winter-run Lifecycle Model: Spawner Abundance

In the CVPIA winter-run SIT life cycle model, mean winter-run Chinook salmon spawner abundance in the central valley under Alternative 4 is similar to the No Action Alternative, with up 4.7% increase in above normal water year types and 0.5% decrease in wet and dry water year types (Attachment F.2, *CVPIA SIT Winter-run LCM*). For all years, the mean annual spawner abundance was similar under Alternative 4 compared to the No Action Alternative. Over the full model run period (1980–1999), abundance under Alternative 4 was similar or slightly lower by 0.4% than abundance under the No Action Alternative. Overall, the spawner abundance predicted by the CVPIA winter-run Chinook salmon life cycle model is expected to be similar under Alternative 4 and the No Action Alternative, with a slight annual decrease in abundance, and increases expected during critically dry and above normal years and decreases expected during above normal and wet years.

IOS: Egg Survival

Under Alternative 4, in critically dry water years, mean predicted winter-run Chinook salmon egg survival is 26.34% higher than when compared to the No Action Alternative. Alternative 4 reflects a change of 0.184 mean predicted winter-run Chinook salmon egg survival when compared to the No Action Alternative (0.698 under the No Action Alternative to 0.882 under Alternative 4). The change in mean predicted winter-run Chinook salmon egg survival in all other water year types less than or equal to 0.000. Alternative 4 provides a substantial benefit to predicted survival of winter-run Chinook salmon eggs during critically dry years when compared to the No Action Alternative.

OBAN: Spawner Abundance and Probability of Quasi-Extinction

Predicted spawner abundance under Alternative 4 is expected to be less under the No Action Alternative (14% less Table O-30). This decrease under Alternative 4 would have an adverse effect on winter-run Chinook salmon.

Probability of quasi-extinction under Alternative 4 was the same as under the No Action Alternative (0.98, Table O-30).

IOS: Female Escapement

Under Alternative 4 in all water year types, mean annual predicted female escapement of winter-run Chinook salmon is 2.21-5.62% higher than when compared to the No Action Alternative. However, the change in mean annual predicted female escapement of in all water year types except below normal ranged from 75-96 individuals. In below normal water years, the change in mean annual predicted female escapement was 206. Alternative 4 provides a slightly positive impact to mean annual predicted female escapement of winter-run Chinook salmon in below normal water years when compared to the No Action Alternative.

OBAN: Egg-to-Fry Survival

Egg to fry survival under Alternative 4 was less than under the No Action Alternative (-0.015 difference, Table O-30). This decrease under Alternative 4 would have an adverse effect on winter-run Chinook salmon.

Redd Dewatering Analysis

The results for Alternative 4 show reduced mean winter-run Chinook salmon redd dewatering potential in wet water years, higher redd dewatering potential in below normal and dry water years, and intermediate values in above normal and critically dry water year types. Winter-run Chinook salmon spawning and incubation occur during late spring through early fall, when flows tend to be less variable. The low percentages of winter-run Chinook salmon redd dewatering in wet years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*) may result from increased stability in project operations related to greater reservoir storage levels. Mean redd dewatering potential is 15.7% higher under Alternative 4 than under the No Project Alternative for wet water year types and 33.3% higher for above normal water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). Mean redd dewatering is 24.2% lower under Alternative 4 than under the No Action Alternatives for critically dry water years and little different for below normal and dry water years.

Overall, the results indicate that redd dewatering potential under Alternative 4 would be similar to than that under the No Action Alternative, with substantial increases in above normal and wet water years and reductions for the other water year types.

Temperature Dependent Mortality

Under Alternative 4 for the Anderson model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.146, 0.608, and 0.007 (less than the No Action Alternative in critically dry, up to 15% less; greater than the No Acton Alternative in wet, up to 133% greater). Expected proportional TDM values for the Anderson model were less under Alternative 4 than No Action Alternative for all water year types except wet.

Under Alternative 4 for the Martin model, expected proportional TDM values calculated across all water year types, for only critically dry water year types, and for only wet water year types were 0.147, 0.585, and 0.015 (less than the No Action Alternative in all but an above normalwater year type, up to 6% less in a wet water year type). Expected proportional TDM values for the Martin model were less under Alternative 4 than No Action Alternative in all water year types except above normal.

Relative to the Anderson model, expected proportional TDM values were higher for the Martin model across all water year types combined and for all water year types except below normal and critically dry. For the Anderson and Martin models, greater than 70% of modeled water years resulted in expected proportional TDM values less than 0.125. For critically dry water year types, 0% of modeled water years resulted in expected proportional TDM values less than 0.5. For above normal and wet water year types only, expected proportional TDM never exceeded 0.125 (Attachment L.2, *Egg-to-fry Survival and Temperature Dependent Mortality*). A decrease in TDM under Alternative 4 compared with the No Action Alternative in all but a wet water year type would generally have a beneficial effect on incubating winter-run Chinook salmon eggs, but could have adverse effects in some water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 16 for Keswick Dam and Table 18 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 20 for Keswick Dam and Table 22 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during May through November are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 24 for Keswick Dam and Table 26 for below Clear Creek.

Results for the three analyses are summarized in Table O-31. Table O-31, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 42.1°F to 55°F range for spawning initiation, there were three to five month-water year type combinations (8.6% to 14.3.0%) with favorable results, depending on location, no combinations (0% of total combinations during the period) with unfavorable results at Keswick Dam, and one combination with unfavorable results below Clear Creek (Table O-31). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were four to six combinations (11.4% to 17.1%) with favorable results, depending on location, no combinations (below Keswick Dam) or one combination (2.9% below Clear Creek) with unfavorable results. These results suggest that there would be mostly no effect or positive biologically meaningful temperature-related effects of Alternative 4 on winter-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River, although there were some negligible negative effects on egg incubation and fry emergence below Clear Creek.

Summary

Alternative 4 relative to the No Action Alternative is expected to have potential adverse impacts on spawning habitat, potential beneficial impacts in critically dry water years, potential adverse to beneficial impacts on spawner abundance dependent on water year type and model, a beneficial impact on female escapement, and no impact on the probability of quasi-extinction due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have a possible beneficial impact using four secondary biological models due to differences in water temperature: IOS, Anderson and Martin (TDM), and OBAN. Using a coarser analysis, Alternative 4 relative to the No Action Alternative is expected to have no impact to beneficial impact on spawning and egg/alevin incubation.

Juvenile Rearing and Emigration

Winter-run Chinook salmon juveniles rear in the Sacramento River primarily from late summer to late winter and emigrate from the river to the Delta beginning in November (see Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). The proportion of juveniles

surviving to emigrate to the Delta depends largely on habitat conditions, including flow and water temperature. Inundated floodplain habitat has been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001a, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 4, mean fry rearing WUA increases in critically dry water year types and decreases in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 1.9% increase in critically dry water years. The largest decrease in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a -0.9% decrease in below normal water year types.

The monthly median value of fry rearing WUA under Alternative 4 is similar to the No Action Alternative throughout the fry rearing period (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Fry rearing WUA median values for all the modeled alternatives are relatively similar September through December but slightly lower in August. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in August in comparison to the other fry rearing months, with an average flow of 10,225 cfs under Alternative 4 (Table O-266). Segment 5, which has the highest distribution of winter-run spawning, has decreased WUA values when flows are between 5,000 and 10,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), leading to lower WUA values during higher flows in August. Winter-run fry rearing WUA starts to increase at flows above 10,000 cfs, and peak at flows around 30,000 cfs. The peak rearing flows are not expected to occur under the No Action Alternative or Alternative 4 during the fry rearing period in the Sacramento River below Keswick Dam. Winter-run Chinook salmon is the only Sacramento River salmonid race or species that shows this pattern.

The results of the winter-run Chinook salmon fry rearing habitat analysis suggest that Alternative 4 may have a minor (less than 2%) increase and/or decrease in estimated fry rearing habitat across all water year types and potentially no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Juvenile Rearing Habitat Analyses

Under Alternative 4, mean juvenile rearing WUA increases in wet and critically dry water year types and decreases in above normal, below normal and dry water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat between Alternative 4 and the No Action Alternative is a 0.7% increase in critically dry water years. The largest reduction in estimated juvenile rearing habitat between Alternative 4 and the No Action Alternative is a -0.5 % decrease in below normal water year types.

The monthly median value of juvenile rearing WUA under Alternative 4 is similar to the No Action Alternative October through January (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are higher in January compared to the other months of juvenile rearing (Table O-266). Segment 5 has decreased WUA values when flows are between 5,000 and 10,000 cfs but the WUA values do not change as drastically with juvenile rearing in comparison to fry rearing (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Winter-run juvenile rearing WUA values start increasing at flows above 15,000 cfs, and peak at flows around 30,000 cfs. These peak rearing flows are not expected to occur under the No Action Alternative or Alternative 4 during the juvenile rearing period in the Sacramento River below Keswick Dam. Winter-run is the only Sacramento River salmonid race or species that shows this pattern.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for winter-run Chinook salmon in the upper Sacramento River under Alternative 4 have a 0.6% to -3.0% difference between the months of October through January in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest reduction in estimated habitat may occur in November under Alternative 4 in comparison to the No Action Alternative.

The results of the two winter-run Chinook salmon juvenile rearing habitat analyses suggest that Alternative 4 may have a negligible (less than 1%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and potentially no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles who generally are stronger swimmers. Alternative 4 shows a large and consistent reduction in stranding of winter-run fry from critically dry to wet water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*) and an increase from July to October (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Winter-run Chinook salmon fry rearing occurs primarily during summer through early fall, when flows tend to be less variable. The minimum rates of stranding for winter-run Chinook salmon fry during wet years may result from increased stability in project operations related to greater reservoir storage levels. Alternative 4 has lower juvenile stranding of winter-run Chinook salmon fry than the No Action Alternative in below normal, dry, and critically dry water years, and higher stranding in wet and above normal water years. The reductions in below normal and critically dry years are 9.1% and 8.7% respectively, but all other differences are less than 5% (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, winter-run Chinook salmon juvenile stranding for fry is lower or little different under Alternative 4 in comparison to the No Action Alternative.

Survival and Travel Time: XT and Flow Survival Threshold Models

Mean daily Sacramento River flows at Keswick Dam and mean daily Sacramento River flows below Wilkins Slough (March 15th to June 15th) are equal to or greater under Alternative 4 compared with the No Action Alternative except during May and June at Keswick Dam in critically dry water year types when flows are less under Alternative 4 compared with the No Action Alternative (Attachment J.4, *XT Model*; Attachment J.5, *Flow Threshold Salmon Survival Model*). The XT and Flow Survival Threshold models provide results that demonstrate the flows under Alternative 4 compared with the No Action Alternative could increase survival and decrease travel time for outmigrating juvenile Chinook salmon on the Sacramento River limiting juveniles' exposure to predation and poor environmental conditions.

Annual mean survival probability under Alternative 4 was greater than annual mean survival probability under the No Action Alternative in all water year types (5% to 7% greater in wet and above normal water year types to up to 20% to 25% greater in critically dry and dry water year types). This increase, particularly in dry and critically dry water year types of up to 25%, would have a large beneficial effect on outmigrating juvenile Chinook salmon. Under both scenarios, average annual mean survival probability was highest during the wet water year types and decreased as the water year type became drier. (Attachment J.5, *Flow Threshold Salmon Survival Model*).

Mean survival probability for outmigrating Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 4 was equal to or greater than mean survival probability under the No Action Alternative (survival equal in wet, above normal, and below normal water year types and to up to 1% greater in dry and critically dry water year types). This increase of up to 1% would have no effect on outmigrating juvenile Chinook salmon. (Attachment J.4, *XT Model*).

Mean travel time (days) for outmigrating winter-run Chinook salmon between Red Bluff Diversion Dam to the confluence of the American and Sacramento rivers and between Red Bluff Diversion Dam to the DCC on the Sacramento River under Alternative 4 was both greater than and less than mean travel time under the No Action Alternative (5% less in dry water year type to the terminus of both reaches and up to 2% greater in wet water year type to the terminus of both reaches). This decrease of 5% may have a minimal effect on outmigrating juvenile winter-run Chinook salmon, particularly dependent on predator presence and environmental conditions (e.g., water temperature) (Attachment J.4, *XT Model*).

Winter-run Juvenile Production Index (JPI)

Under Alternative 4, the mean predicted JPI is generally lower than No Action Alternative, ranging from 5.9% higher in 2020 to 27.68% lower in 2014. In 15 of the years analyzed (2002-2021), the JPI was lower under Alternative 4 than the No Action Alternative, six of those years being over a 10.00% lower and three over 5.00% lower. These results suggest that Alternative 4 is expected to have a negative effect on the number of juveniles produced annually when compared to the No Action Alternative.

IOS: Fry Survival and Juvenile River Migration Survival

Under Alternative 4, in critically dry water years, mean predicted winter-run Chinook salmon fry survival is 19.97% higher than when compared to the No Action Alternative (Attachment F.5, *Interactive Object-oriented Simulation Model (Winter-run Chinook Salmon*). Alternative 4 reflects a change of 0.13 mean predicted winter-run Chinook salmon fry survival when compared to the No Action Alternative (0.65 under the No Action Alternative to 0.782 under Alternative 4). The change in mean predicted winter-run Chinook salmon fry survival in all other water year types was less than or equal to ± 0.003. Alternative 4 provides a substantial benefit to predicted survival of winter-run Chinook salmon fry during critically dry water years when compared to the No Action Alternative.

Under Alternative 4, in all water years, mean predicted river migration survival of winter-run Chinook salmon juveniles is higher than when compared to the No Action Alternative. However, the change in mean predicted river migration survival in all water year types less than or equal to 0.002. There is not a substantial difference in predicted river migration survival of winter-run Chinook salmon juveniles between Alternative 4 and the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during July through December are presented in Attachment L.1, Sacramento River Water Temperature Analysis, Table 28 for Keswick Dam, Table 30 for Red Bluff Diversion Dam, and Table 32 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during July through December are presented in Attachment L.1, Sacramento River Water Temperature Analysis, Table 34 for Keswick Dam, Table 36 for Red Bluff Diversion Dam, and Table 38 for Hamilton City.

Results for the two analyses are summarized in Table O-32. Table O-32, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 55.4°F to 68°F optimum water temperature range analysis, there were zero to two month-water year type combinations (0% to 6.7% of total combinations during the period) with favorable results, depending on location, and there were zero to three combinations (0% to 10%) with unfavorable months, depending on location (Table O-32). For the 75.2°F upper incipient lethal temperature under Alternative 4, there would be no favorable or unfavorable results at any location. These results suggest that there would be positive and negative water-temperature-related effects on winter-run Chinook salmon juvenile rearing and outmigration in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have potential beneficial to adverse impacts on fry and juvenile rearing habitat, a slightly beneficial impact to no impact on fry stranding, adverse impact on the juvenile production index, and a beneficial impact on fry survival particularly in critically dry years due to differences in flow. Alternative 4 relative to the No Action Alternative could have an adverse to beneficial impact in all water year types, potential beneficial dependent on model, on individuals' survival and travel time in the upper Sacramento River due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have adverse and beneficial water temperature-related impacts on juvenile rearing and emigration.

Adult Upstream Migration and Holding

Winter-run Chinook salmon adults enter the Sacramento River from the Delta and make their way to the upper Sacramento River, beginning as early as December through late spring (May/June) (see Section O.1.3.2.1, *Winter-run Chinook Salmon, Sacramento River ESU*). They hold in the upper River within 10 to 15 miles of Keswick Dam until they are ready to spawn, which may extend through August (Windell et al. 2017). Most of the run passes Red Bluff Diversion Dam from January to May with the peak in mid-March (Hallock and Fisher 1985).

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

CalSim 3 Flows

During the December through May/June period of adult winter-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 4 at Sacramento River below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough generally be similar to or greater than flows under the No Action Alternative, except a decrease at all three locations in May and June of a critically dry water year type (up to 6% lower). At Sacramento River below Keswick Dam flows under Alternative 4 would range from less than to greater than flows under the No Action Alternative, depending on month and water year type, generally similar to or greater than flows under the No Action in December through April) and generally less than flows under the No Action Alternative May and June of critically dry years Flows at Hamilton City and Wilkins Slough under Alternative 4 would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 4 between December and May/June would be greater than 5,200 cfs at Wilkins Slough and greater than 7,500 cfs at Hamilton City (Table O-267, Table O-266, Table O-268, Table O-269).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range for winter-run Chinook salmon adult migration and holding are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 4 for Keswick Dam, Table 6 for Red Bluff Diversion Dam, and Table 8 for Hamilton City.

Results are summarized in Table O-33. Table O-33, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Table O-33 indicates that, under Alternative 4, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at all locations, except Hamilton City, at which there was one combination (3.3%) with an unfavorable result (Table O-33). These results suggest that there would be minimal effects of Alternative 4 on water temperature conditions for winter-run Chinook salmon adult migrants in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have no impact to a minimal beneficial impact, depending on location and month except June of critically dry water year type, on upstream migrating and holding adult winter-run Chinook salmon, average monthly flows at Hamilton City and Wilkins Slough are high enough to allow upstream passage. Differences in temperature between Alternative 4 and the No Action Alternative are expected to have minimal impact on upstream migrating and holding adult winter-run Chinook salmon.

O.7.8.2 Bay-Delta

Juvenile Rearing and Emigration

Rearing winter-run Chinook salmon are present in the Delta from October to May (see Section O.1.9.1.1, *Winter-run Chinook Salmon, Sacramento River ESU*). Key habitat attributes relevant to seasonal operations in the Delta include out-migration cues and entrainment risk. Juveniles enter the Delta primarily during December through April and most emigrate past Chipps Island by the end of April but can potentially exit as late as May (Brandes and McLain 2001; del Rosario et al. 2013). A critical assumption in these analyses is LAD criteria used to identify juveniles (vs genetic ID) are sufficient to represent juveniles' downstream migration patterns.

Potential Changes to Winter-run Chinook Salmon from Seasonal Operations

Zone of Influence

The proportional overlap of Alternative 4 (pumping vs no pumping) was less than proportional overlap of the No Action Alternative (pumping vs no pumping) at Turner Cut under all OMR bins except < -5,500 (Attachment I.3, *Delta Export Zone of Influence Analysis*). The proportional overlap of Alternative 4 (pumping vs no pumping) was less than proportional overlap of the No Action Alternative (pumping vs no pumping) at the San Joaquin River at Jersey Point under the two OMR bins (-2,000 and -5,000). The proportional overlap of Alternative 4 (pumping vs no pumping) was less than proportional overlap of the No Action Alternative (pumping vs no pumping) at Old River at Middle River under the most positive OMR bins (-2,000).

With incremental decreases in OMR under Alternative 4 and the No Action Alternative, proportional overlap at these three locations decreases, with more subtle changes along the San Joaquin River at Jersey Point compared to Turner Cut and Old River at Middle River. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping.

Flow into Junctions

For a full description of Flow into Junctions model background, see Section O.4.8.2, *Sacramento River Winter-run Chinook Salmon ESU, Juvenile Rearing and Emigration in the Bay-Delta*. The following section covers discussion of the Central Valley Project and Head of Old River junctions. An expanded set of junction analysis results can be found in Attachment I.10, *Flow into Junctions*.

Under Alternative 4 in all OMR bins except -3,500, predicted proportion of flow entering the Central Valley Project is less than the No Action Alternative. Changes in predicted proportion of flow entering the CVP in OMR bins -3,500, -5,000, and <-5,500 was less than ± 0.0372, indicating a negligible difference between Alternative 4 and the No Action Alternative. However, in OMR bin -2,000 the change in predicted proportion of flow into CVP was -0.0676 indicating that slightly less flow will be routed into CVP under Alternative 4 than when compared to the No Action Alternative.

Under Alternative 4 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the Head of Old River (HOR) is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.026, indicating a negligible difference between Alternative 4 and the No Action Alternative.

Summary

Alternative 4 relative to the No Action Alternative is expected to influence flow into the HOR and CVP junctions differences in water management. Under Alternative 4, no change to possibly less flow into CVP under OMR -2,000; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 4 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Winter-run Chinook Salmon

Salvage Density and Negative Binomial

Predictions from the salvage density model for genetic and LAD winter-run Chinook salmon include mean monthly total exports. Predictions from the negative binomial loss model for LAD winter-run Chinook salmon include mean monthly total exports and mean monthly San Joaquin River flows at Vernalis. Table O-271 shows modeled mean monthly total exports at SWP and CVP and Table O-281 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of genetic winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through May of all water year types for Alternative 4 had greater than predicted average monthly loss under the No Action Alternative. Predicted loss of genetic winter-run Chinook salmon at Banks under Alternative 4 was up to 17% higher than the No Action Alternative for critically dry water year types (Table O-36). Predicted average monthly loss of genetic winter-run Chinook salmon at CVP Jones Pumping Plant for all the

months December through April for Alternative 4 was greater than predicted average monthly loss under the No Action Alternative for wet, above normal, and below normal water year types, with up to a 10% increase for wet water year types. Predicted loss of genetic winter-run Chinook salmon under Alternative 4 compared to the No Action Alternative for dry and critically dry water year types was lower, with up to a 3% decrease in predicted loss for the critically dry water year types (Table O-37). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly loss of LAD winter-run Chinook salmon at SWP Banks Pumping Plant for all the months December through April, and of all water year types, Alternative 4 was greater than predicted average monthly loss under the No Action Alternative. Predicted loss of LAD winter-run at Banks under Alternative 4 compared to the No Action Alternative for all water year types had an increase of up to 135% for wet water year types. (Table O-34). Predicted average monthly loss of LAD winter-run Chinook salmon at CVP Jones Pumping Plant for all the months December through April Alternative 4 was greater than predicted average monthly loss under the No Action Alternative for wet, above normal, and below normal water year types with up to a 7% increase for the above normal water year types. Predicted loss of LAD winter-run Chinook salmon at CVP Jones Pumping Plant from Alternative 4 compared to the No Action Alternative for dry and critically dry water year types had a decrease in predicted loss of up to 1% for both water year types (Table O-35). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly salvage of LAD winter-run Chinook salmon at the Delta fish collection facilities for the months of December through April under Alternative 4 was higher than predicted average monthly salvage under the No Action Alternative for all water year types. Predicted loss for genetic and LAD winter-run Chinook salmon under Alternative 4 compared to the No Action Alternative had an increase in predicted loss of up to 28% for wet water year types (Table O-38). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

<u>Winter-run Chinook Salmon Coded Wire Tag Salvage Model</u>

Predicted mean of annual and monthly proportion of winter-run Chinook salmon salvaged at CVP and SWP for all months October through May under Alternative 4 in all water year types, varied from positive to negative between months when compared to the No Action Alternative (Attachment I.9,, *Winter-run Chinook Salmon Coded Wire Tag Salvage Model*). Salvage is predicted to increase in wet years under Alternative 4 when compared to the No Action Alternative, however all predicted proportion salvaged are less than ± 0.01 in all months and years. Overall, there is not a substantial difference in predicted proportion salvaged between Alternative 4 and the No Action Alternative.

<u>Summary</u>

Alternative 4 relative to No Action Alternative are largely expected to have a possible substantial adverse impact on the entrainment of genetically and LAD identified juvenile winter-run Chinook salmon in the Delta at both fish facilities due to differences in flow, supported by results from two quantitative models. However, differences in flow between Alternative 4 and the No Action Alternative are expected to have a possible minimal beneficial impact on entrainment during dry and critically dry water year types. A third model suggests no impact of differences in

flow between Alternative 4 and the No Action Alternative on predicted salvage proportion of juvenile winter-run Chinook salmon.

Potential Changes to Routing of Winter-run Chinook Salmon

STARS

Average Sacramento River flows at Freeport December through May are similar under Alternative 4 compared with the No Action Alternative. The STARS model is responsive to modeled Freeport flows and daily operations of the DCC gates, both obtained from CalSim 3.

The STARS model provides predictions of routing and survival probabilities, in this section routing results are discussed. In the "survival" section survival results are discussed. Mean proportion of particles routed to the Interior Delta via either Georgiana Slough or the DCC), averaged across all water year types by month under Alternative 4 was equal to or less than the No Action Alternative for all months December through April except January where a 0.5% increase was predicted (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). The difference in proportion of particles routed to the Interior Delta under Alternative 4 is minimal and would likely have no effect on outmigrating juveniles.

ECO-PTM

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under Alternative 4 ranged from less than the No Action Alternative (up to 7% less under <-5,500 cfs) to greater than the No Action Alternative (up to 12% greater under -3,500 cfs) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in the attachment. The decrease in routing to the Interior Delta could have a beneficial effect on outmigrating juveniles while the increase in routing could have an adverse effect on outmigrating juveniles.

Summary

Two flow-based quantitative models suggest depending on considered variables, flows under Alternative 4 relative to the No Action Alternative may be adverse or beneficial for outmigrating juvenile Chinook salmon when results are binned by OMR grouping. Alternative 4 relative to the No Action Alternative's STARS modeling results suggest little to no impact on routing into the Interior Delta. Alternative 4 relative No Action Alternative using ECO-PTM suggest a potential adverse or beneficial impact dependent on OMR grouping.

Potential Changes to Through Delta Survival of Winter-run Chinook Salmon

Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. Juvenile Chinook salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010, 2018).

Differences in monthly flows on the Sacramento River under Alternative 4 compared with the No Action Alternative may have effects on juvenile Chinook salmon's routing and survival probabilities in the Sacramento River. These possible differences were evaluated using several quantitative models: STARS, ECO-PTM, the Delta Passage Model, IOS, and OBAN.

STARS

Average Sacramento River flows at Freeport December through May are similar under Alternative 4 compared with the No Action Alternative. The STARS model is responsive to modeled Freeport flows and daily operations of the DCC gates, both obtained from CalSim 3.

The STARS model provides predictions of routing and survival probabilities, in this section survival results are discussed. In the "routing" section routing results are discussed. Mean predicted through-Delta survival of particles across all routes, averaged across all water year types by month under Alternative 4 was minimally greater than the No Action Alternative in all months December through April (up to 0.4% in April and December) (Attachment I.5, *Survival, Travel Time, and Routing Simulation Model*). This minimal increase in survival would have no effect on outmigrating juveniles.

ECO-PTM

Mean through-Delta percent survival December through March under Alternative 4 ranged from less than the No Action Alternative (up to 5% less under -3,500 cfs) to greater than the No Action Alternative (up to 6% more under <-5,500 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in the attachment. The increase in survival under some OMR conditions could have a beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have an adverse effect on outmigrating juveniles.

Delta Passage Model

Under Alternative 4, in all water year types except dry water years, predicted mean survival of winter-run Chinook salmon to Chipps Island is higher than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). The change in mean predicted survival to Chipps Island in all water year types was less than or equal to 0.001..

IOS: Through-Delta Survival

Under Alternative 4 in above normal and critically dry water years only, mean predicted through Delta survival of winter-run Chinook salmon juveniles is lower than when compared to the No Action Alternative. The change in mean predicted river migration survival in all water year types less than or equal to ± .005.

OBAN: Delta Survival

Delta survival under Alternative 4 was less than under the No Action Alternative (1.1% less, Table O-30). This decrease would have a minimal adverse effect on outmigrating juvenile winter-run Chinook salmon.

Summary

Alternative 4 relative to the No Action Alternative are largely expected to have a possible adverse to beneficial impact on survival of outmigrating juvenile winter-run Chinook salmon dependent on model due to differences in flow. Alternative 4 relative to the No Action Alternative are expected to have a possible minimal beneficial impact in all months December through April (STARS), minimal adverse impact (OBAN), adverse or beneficial impact dependent on OMR grouping (ECO-PTM), or no impact (DPM, IOS).

O.7.9 Central Valley Spring-run Chinook Salmon ESU

O.7.9.1 Sacramento River

Spawning and Egg/Alevin Incubation

Spring-run Chinook salmon adults spawn from August through October (Williams 2006) with peak spawning in September (see Section O.1.3.2). Monitoring spring-run Chinook salmon spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from fall-run Chinook salmon. Most spring-run Chinook salmon spawning occurs between the Keswick Dam and Ball Ferry Bridge (National Marine Fisheries Service 2017c). Fry emergence occurs up to three months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating spring-run Chinook salmon eggs and alevins potentially occur from August through January, peaking in December.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 4, mean spawning WUA increases in wet and critically dry water year types and lower in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 4 and the No Action Alternative is a 3.2% increase in critically dry water year types for Alternative 4. The largest reduction in estimated spawning habitat is a -2.2% decrease for Alternative 4 in above normal water year types (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The monthly median value of spawning WUA under Alternative 4 is similar to the No Action Alternative for the three months of spring-run spawning (August–October) (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA for all of the modeled alternatives are substantially lower in August than in September or October. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently higher in August than in the other two months (Table O-266). This results in lower spawning WUA results because the fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), which were used to estimate spring-run spawning WUA, peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of suitable habitat availability analysis using the SIT LCM habitat models indicate that spawning habitat for spring-run in the upper Sacramento River may not be a limiting factor under both the No Action Alternative and Alternative 4 (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The results of the two spawning habitat analyses based on CalSim 3 simulated flows suggest that Alternative 4 has a minor (less than 3.5%) increase and/or decrease on estimated spawning habitat when compared to the No Action Alternative, and that spawning habitat may not be a limiting factor for spring-run Chinook salmon in the mainstem upper Sacramento River.

SIT Spring-run Lifecycle Model: Spawner Abundance

In the CVPIA spring-run SIT life cycle model, mean spring-run Chinook salmon spawner abundance in the Central Valley under Alternative 4 in Chinook salmon spawner abundances are similar to the No Action Alternative in the Central Valley, with up to 0.1% increase in wet water year types and 0.1% decrease in dry and above normal water year types (Attachment F.3, *CVPIA SIT Spring-run LCM*). Over the full model run period (1980–1999), abundance under Alternative 4 was equal to abundance under the No Action Alternative. Overall, the spawner abundance predicted by the CVPIA spring-run life cycle model is expected to be similar under Alternative 4 and the No Action Alternative.

Redd Dewatering Analysis

Under Alternative 4, the spring-run Chinook salmon redd dewatering results show a consistent reduction from wetter to drier water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation is expected for spring-run Chinook salmon because their spawning occurs in the fall, with incubation extending into early winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering potential. In drier winters, flow fluctuations are reduced and fewer redds are dewatered. Mean redd dewatering potential is much lower under Alternative 4 than under the No Action Alternative in wet, above normal, and critical water years but differences are minor for below normal and dry water year types. The largest reduction is 40.4% for above normal water years and the only increase is 2.3% for dry years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). For individual month periods, redd dewatering is moderately higher for September spawning than for October spawning (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that redd dewatering potential would be lower under Alternative 4 than under the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 48 for Keswick Dam and Table 50 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 54 for Keswick Dam and Table 56 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during September through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 60 for Keswick Dam and Table 62 for Red Bluff Diversion Dam.

Results for the three analyses are summarized in Table O-39. Table O-39, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 42.1°F to 55°F spawning initiation range analysis, there were six and zero month-water year type combinations (17.1% and 0% of total combinations during the period) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively (Table O-39). There were zero and one combinations (0% and 2.9%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. For the 59.9°F pathogen virulence threshold, there were three and seven combinations (8.6% and 20.0%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively, and there were zero and three combinations (0% and 8.6%) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were two and zero combinations (5.7% and 0%) with favorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively, and zero and two combinations (0% and 5.7%, respectively) with unfavorable results below Keswick Dam and at Red Bluff Diversion Dam, respectively. These results suggest that there would be positive and negative effects of Alternative 4 on spring-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative are expected to have negligible impacts on spring-run Chinook salmon spawning, spawner abundance and egg/alevin incubation (mortality) due to differences in flow. There is a beneficial impact on redd dewatering, with lower redd dewatering potential in wet, above normal water years, and critically dry water years and little difference in below normal and dry water years. Flow for spawning habitat is not a limiting factor for spring-run Chinook salmon. Water temperatures for spawning and egg/incubation will have beneficial and adverse impacts under Alternative 4 compared to the No Action Alternative.

Juvenile–Yearling Rearing and Emigration

Spring-run Chinook salmon juveniles rear in the Sacramento River primarily from November through June and most emigrate to the Delta during December and again in March and April (Roberts 2007) (see Section O.1.3.2, *Spring-run Chinook Salmon*). Migratory cues, such as increased flow and/or turbidity from runoff, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (National Marine Fisheries Service 2009a). Inundated floodplain habitats have been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001a, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 4, mean fry rearing WUA increases in wet and above normal water year types and decreases in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increases in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 0.1% increase in wet water year types. The largest reduction in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a -0.8% decrease in below normal water year types.

The monthly median value of fry rearing WUA under Alternative 4 is similar to the No Action Alternative January through April (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Fry rearing WUA median values for all the modeled alternatives are similar across December, January, and March, which are important months for rearing. The results during these three months show little variation in the third quartile of the WUA distributions. This occurs because the fry rearing WUA curves peak at the lowest flows encountered in the river (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and Keswick Dam flow releases are frequently low during these months in critically dry years when Shasta Reservoir is operated to rebuild storage volume (Table O-266). The first quartile is much wider because a greater range of flows affect the fry rearing WUA values below the median. November and April have the lowest median WUA values across all alternatives.

The results of the fry rearing habitat analysis suggest that Alternative 4 may have a negligible (less than 1%) increase and/or decrease in estimated spring-run fry rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative.

Juvenile Rearing Habitat Analyses

Under Alternative 4, juvenile rearing WUA decreases in all water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). There are no increases in estimated juvenile rearing habitat under Alternative 4 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat is a 1.4% decrease in critically dry water year types between Alternative 4 and the No Action Alternative.

The monthly median value of juvenile rearing WUA under Alternative 4 is similar to the No Action Alternative January through May (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under all the modeled alternatives are similar for January through March, but they are generally lower for April and May. For the January through March period, as described above for spring-run Chinook salmon fry rearing WUA, the third quartiles of the WUA distributions have high values and reduced variation. This reduced variation occurs because, as described for the fry rearing WUA curves, the juvenile rearing WUA curves peak at the lowest flows encountered in the river (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and low flows are frequent during January through March in dry and critically dry years when Shasta Reservoir is operated to rebuild storage (Table O-266).

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for spring-run in the upper Sacramento River show a 0.7% to -1.1% difference between the months of January and May (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated spring-run habitat may occur in the month of May and the greatest reduction in estimated habitat may occur in January under Alternative 4 in comparison to the No Action Alternative.

The results of the two spring-run Chinook salmon juvenile rearing habitat analyses suggest that Alternative 4 may have a minor (less than 2%) increase and/or decrease in estimated juvenile rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in comparison to the No Action Alternative in the mainstem upper Sacramento River.

Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Alternative 4 shows an increase in mean stranding of spring-run fry from critically dry, dry, and below normal water years to above normal and wet years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher mean stranding levels for spring-run fry during wetter water year types likely results from increased variability of flow. Spring-run Chinook salmon fry rearing occurs primarily during late fall and winter. For individual months, Alternative 4 shows the highest median stranding in November and lowest median stranding in December and January, with February median stranding at an intermediate level (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Fry stranding means are lower under Alternative 4 than under the No Action Alternative in all water year types except for a 10.0% increase in critically dry water year types (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The reductions range from 0.6% lower in below normal water years to 6.6% lower in dry water years.

Overall, spring-run stranding of fry is slightly lower under Alternative 4 relative to the No Action Alternative, except for an increase in stranding under critically dry water years.

Survival and Travel Time: XT and Flow Survival Threshold Models

For a detailed description of how flows under Alternative 4 may impact juveniles and yearlings' travel time and survival probabilities in the Upper Sacramento River, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.1).

Results from the Flow Survival Threshold model indicate that the average annual mean survival probability of juvenile Chinook salmon is always highest during wetter years and lowest during drier years. For all water year types, the annual mean survival probability is greater under Alternative 4 than under the No Action Alternative, ranging from 5% greater in wet water years to 25% dry water years (Attachment J.5, *Flow Threshold Salmon Survival Model).*

The XT model results indicate that mean travel times from Red Bluff Diversion Dam both to the confluence of the American and Sacramento rivers and to the DCC range from negligibly higher under Alternative 4 than under the No Action Alternative for wet years (+1%) to 5% less for dry years, with potentially minimal positive effects on outmigrating juvenile Chinook salmon. The mean survival probability as indicated by the XT model for the same reaches was essentially similar under Alternative 4 and the No Action Alternative (up to 1% greater in dry and critically dry water years). (Attachment J.4, *XT Model*).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for juvenile growth, smoltification, and predation vulnerability during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 66 for Keswick Dam, Table 68 for RBDD, and Table 70 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating juveniles during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 74 for Keswick Dam, Table 76 for RBDD, and Table 78 for Hamilton City. Full results of

the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for yearling growth, smoltification, and predation vulnerability are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 82 for Keswick Dam during April through December, Table 84 for RBDD during April through December, and Table 98 for Hamilton City during October through December (migration only). Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating yearlings are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 88 for Keswick Dam during April through December, Table 90 for RBDD during April through December, and Table 106 for Hamilton City during October through December (migration only).

Results for the four analyses are summarized in Table O-40. Table O-40, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F juvenile optimum temperature range under Alternative 4, there were zero to two month-water year type combinations (0% to 6.7% of total combinations during the period) with favorable results depending on location (Table O-40). There were zero to two combinations (0% to 5.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles under Alternative 4, there would be no combinations with either favorable or unfavorable results at any location. For the 55.4°F to 68°F yearling optimum temperature range under Alternative 4, there would be zero combinations (0%) with favorable results at each location. There would be zero to five combinations (0% to 11.1%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating yearlings under Alternative 4, there would be no combinations (0%) with either favorable or unfavorable results at any location.

These results indicate that there would generally be a mix of favorable and unfavorable water temperature-related conditions under Alternative 4 related to optimum water temperatures on juveniles and yearlings, and there would be no exacerbation of lethal water temperatures at any location associated with Alternative 4.

<u>Summary</u>

Alternative 4 relative to the No Action Alternative is largely expected to be similar, with negligible impact on spring-run Chinook salmon juvenile and yearling rearing habitat due to differences in flow. There is a minor beneficial impact on stranding in comparison to the No Action Alternative, except for an adverse impact in critically dry years. Annual mean survival would have a beneficial impact, and mean survival is negligible or slightly beneficial compared to the No Action Alternative. Travel time was mixed, with both beneficial and adverse impacts. Water temperatures for optimum juvenile and yearling rearing is a mix of minor beneficial and adverse water temperature-related conditions under Alternative 4 and there would be negligible impacts of Alternative 4 on lethal temperatures at all locations.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon enter the San Francisco Estuary from the Pacific Ocean to begin their upstream spawning migration in late January and early February (California Department of Fish and Wildlife 1998). Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). While maturing, adults hold in deep pools with coldwater. Documentation of holding locations in the Sacramento River was not identified.

Spring-run Chinook salmon adults enter the Sacramento River from March to September, primarily in May and June (Moyle 2002; Yoshiyama et al. 1998). In the upper Sacramento River, migration extends from mid-March through July with peak migration in late May and early June (California Department of Fish and Wildlife 1998).

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

CalSim 3 Flows

During the January through June/July period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 4 at Sacramento River below Keswick Dam, below Red Bluff Diversion Dam, Hamilton City, and Wilkins Slough would generally be similar to flows under the No Action Alternative. Flows under Alternative 4 in May, June and July during critically dry years would decrease below Keswick Dam and below Red Bluff Diversion Dam, while during critically dry years flows under Alternative 4 would decrease in July at Hamilton City and Wilkins Slough compared to the No Action Alternative Flows at all sites range from -5% to -11% at Keswick Dam in May during a critically dry year. Flows at Hamilton City under Alternative 4 would be high enough (> 3,250 cfs) to allow upstream passage. The average monthly flows across all water year types under Alternative 4 between January and June/July would be greater than 5,500 cfs at Wilkins Slough (except in June) and greater than 7,500 cfs at Hamilton City (Table O-266 through Table O-269).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during March through September are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 40 for Keswick Dam, Table 42 for RBDD, and Table 44 for Hamilton City.

Results for the analysis are summarized in Table O-41. Table O-41, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4, there were zero to two month-water year type combinations (0% to 5.7% of total combinations during the period) with favorable results and zero to two combinations (0% to 5.7%) with unfavorable results, depending on location (Table O-41). These results suggest that there would be mostly negligible water temperature-related effects of Alternative 4 on spring-run Chinook salmon migration and holding in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts, on upstream migrating and holding adult spring-run Chinook salmon, except in May during critically dry years when there could be an adverse impact due to differences in flow. Average monthly flows at Hamilton City and Wilkins Slough are high enough to allow upstream passage. Differences in water temperatures between Alternative 4 and the No Action Alternative are expected to have negligible impacts on upstream migrating and holding adult spring-run Chinook salmon.

O.7.9.2 Clear Creek

Spawning and Egg Incubation

Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities to promote higher oxygen levels. Spawning in Clear Creek normally occurs between mid-August and early October, peaking in September (Moyle 2002).

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 4, mean spawning WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean spawning WUA under Alternative 4 in comparison to the No Action Alternative. The largest reduction in estimated spawning habitat is a 12.7% decrease in below normal water year types. On average across all water year types, there is an 11.9% reduction in estimated spawning habitat under Alternative 4.

The mean values of spawning WUA by month are lower under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). October is expected to have the highest spawning WUA values under the four phases of Alternative 4.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that spawning habitat for spring-run in Clear Creek may be a limiting factor under all of the modeled alternatives and that spawning habitat may decrease 9.5-11.1% in September and October for Alternative 4 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The two spawning habitat analyses indicate that Alternative 4 may have an adverse impact, as spring-run Chinook salmon spawning habitat may decrease on average by 11.9% across all water year types in Clear Creek when compared to the No Action Alternative, and that spawning habitat may be a limiting factor for spring-run Chinook salmon in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 52 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water

temperature above the 59.9°F adult pathogen virulence threshold during April through October are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 58 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during September through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 6 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-42. Table O-42, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-42). For the 59.9°F pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be no water temperature-related effects of Alternative 4 on spring-run Chinook salmon spawning in Clear Creek.

Summary

Alternative 4 relative to the No Action Alternative is expected to have adverse impacts on spawning habitat area due to a decrease in flows. There are no anticipated water temperature-related effects of Alternative 4 relative to the No Action Alternative.

Juvenile–Yearling Rearing and Emigration

While the majority of juvenile spring-run Chinook salmon outmigrate as fry, a proportion rears in Clear Creek through the spring and summer and emigrates as sub-yearlings with the first rainstorms in the fall or winter following their birth (National Marine Fisheries Service 2014a). Spring-run Chinook salmon outmigration from Clear Creek occurs during late October through late April with peak emigration of juveniles occurring in November, and few fish exiting through the end of May.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 4, mean fry rearing WUA increases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is an 8.0% increase in dry water year types. There are no anticipated reductions in mean fry rearing WUA under Alternative 4 in comparison to the No Action Alternative.

The mean values of fry rearing WUA by month are generally higher under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the five fry rearing months, January and February are expected to have the highest fry rearing WUA values under the four phases of Alternative 4.

The results of the spring-run Chinook salmon fry rearing habitat analysis indicate that Alternative 4 may have up to an 8.0% increase in estimated spring-run Chinook salmon fry rearing habitat across all water year types in Clear Creek.

Juvenile Rearing Habitat Analyses

Under Alternative 4, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 4 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 4 and the No Action Alternative is a 5.7% decrease in critically dry water year types. On average across all water year types, there is a 5% reduction in estimated juvenile rearing habitat under Alternative 4.

The mean values of juvenile rearing WUA by month are lower June through August and higher in April and May under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the five juvenile rearing months, May and June are expected to have the highest juvenile rearing WUA values.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for spring-run Chinook salmon in Clear Creek may decrease 12.4-15.0% during the summer months (June through August) but may increase 4.2-12.6% in the spring months April and May under Alternative 4 compared to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest decrease in estimated juvenile rearing habitat may occur in June and the greatest increase in estimated juvenile rearing habitat may occur in May.

The results of the two spring-run Chinook salmon juvenile rearing habitat analyses indicate that Alternative 4 may have a minor adverse effect, as rearing habitat may decrease on average by 5% across all water year types in comparison to the No Action Alternative, and that there may be increases to habitat in the spring and reductions in habitat in the summer in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for juvenile growth, smoltification, and predation vulnerability during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 72 below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating juveniles during November through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 80 below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature range for yearling growth, smoltification, and predation vulnerability are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 86 below

Whiskeytown Dam April through December. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F UILT for rearing and migrating yearlings are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 92 below Whiskeytown Dam for April through December.

Results for the four analyses are summarized in Table O-43. Table O-43, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 55.4°F to 68°F juvenile optimum temperature range under Alternative 4, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-43). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 55.4°F to 68°F yearling optimum temperature range, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 75.2°F UILT for rearing and migrating yearlings, there were no combinations (0%) with favorable results and two combinations (4.4%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on spring-run Chinook salmon juvenile and yearling rearing and emigration in Clear Creek.

Summary

Alternative 4 relative to the No Action Alternative is expected to be beneficial during all water years for spring-run Chinook salmon fry rearing habitat but may have an adverse impact on juvenile spring-run Chinook salmon rearing habitat due to differences in flow. Differences in water temperatures are negligible so are not expected to affect fry and juvenile rearing and emigration.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon migrate into Clear Creek from April to August, and peak passage occurs in May and June (Clear Creek Technical Team 2018; Giovannetti et al 2013). Adults distribute throughout Clear Creek and hold in deep pools throughout the summer from Whiskeytown Dam (river mile 18.3) as far downstream as river mile 4.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

CalSim 3 Flows

During the April through August period of adult spring-run Chinook salmon immigration and holding, the mean monthly flows under Alternative 4 will be increased in April and May in all water years and reduced from June to August which range from 3% in July in all water years, up to 36% in June during a critically dry year. Average flows range from 112 cfs in July to 261 cfs in May (Table O-275).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during March through September are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 46 below Whiskeytown Dam.

Results for the analysis are summarized in Table O-44. Table O-44, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 37.9°F to 68°F successful adult migration range, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-44). These results suggest that there would be no water temperature-related effects of Alternative 4 on spring-run Chinook salmon adult upstream migration and holding in Clear Creek.

Summary

Alternative 4 relative to the No Action Alternative may have an adverse impact from June to August on upstream migrating and holding adult spring-run Chinook salmon due to differences in flow. There would be no water-temperature related effects of Alternative 4 relative to the No Action Alternative.

O.7.9.3 Bay-Delta

Juvenile–Yearling Rearing and Emigration

Juvenile spring-run Chinook salmon show two distinct out-migration patterns in the Central Valley: out-migrating to the Delta and ocean during their first year of life as YOY or holding over in their natal streams and out-migrating the following fall/winter as yearlings. YOY spring-run Chinook salmon presence in the Delta peaks during April and May, as suggested by the recoveries of Chinook salmon in the CVP and SWP salvage operations and the Chipps Island trawls of a size consistent with the predicted size of spring-run fish at that time of year.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Zone of Influence

Differences in hydrology under Alternative 4 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. With incremental decreases in OMR under Alternative 4 and the No Action Alternative, proportional overlap at these three locations decreases, with more subtle changes along the San Joaquin River at Jersey Point compared to Turner Cut and Old River at Middle River. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under Alternative 4 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2, *Zone of Influence*).

Flow into Junctions

Differences in flow routing under Alternative 4 compared with the No Action Alternative may have effects on the flow into the Head of Old River and CVP junctions.

Under Alternative 4 in all OMR bins except -3,500, predicted proportion of flow entering the CVP is less than the No Action Alternative. Changes in predicted proportion of flow entering the CVP in OMR bins -3,500, -5,000, and <-5,500 was less than ± 0.0372, indicating a negligible difference between Alternative 4 and the No Action Alternative. However, in OMR bin -2,000 the change in predicted proportion of flow into CVP was -0.0676 indicating that slightly less flow will be routed into CVP under Alternative 4 than when compared to the No Action Alternative.

Under Alternative 4 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the Head of Old River (HOR) is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.026, indicating a negligible difference between Alternative 4 and the No Action Alternative.

For a detailed description of how flows under Alternative 4 may impact the flow at HOR and CVP, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2, *Flow into Junctions*).

Summary

Alternative 4 relative to the No Action is expected to influence flow into the HOR and CVP junctions. Under Alternative 4, no change to possibly less flow into CVP under OMR -2,000; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 4 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Spring-run Chinook Salmon

Salvage Density and Negative Binomial

Predictions from the salvage density and the negative binomial model for LAD spring-run Chinook salmon include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP and Table O-281 shows modeled mean monthly flows of the San Joaquin River at Vernalis. Refer to the tables for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of LAD spring-run Chinook salmon at SWP Banks Pumping Plant for all the months January through June for Alternative 4 was greater than predicted average monthly loss under the No Action Alternative for all water year types with up to a 117% increase in predicted loss for above normal water year types (Table O-45). Predicted average monthly loss of LAD spring-run Chinook salmon at CVP Jones Pumping Plant for all the months December through June for Alternative 4 was higher than predicted average monthly loss under the No Action Alternative for all water year types except for dry water year types that had a

decrease in predicted loss of 1%. Predicted average monthly loss at Jones for LAD spring-run under Alternative 4 compared to the No Action Alternative increased for wet, above normal, below normal, and critically dry water year types, with up to a 5% increase for below normal water year types (Table O-46). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly salvage of LAD spring-run Chinook salmon at the Delta fish collection facilities for the months of March through June under Alternative 4 was greater than predicted loss under the No Action Alternative for all water year types, with up to a 97% increase in predicted loss for above normal water year types. (Table O-47). For detailed information on average monthly salvage by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Summary

Alternative 4 relative to the No Action Alternative resulted in an increase of entrainment due to differences in flow. Average monthly loss and salvage of LAD spring-run Chinook salmon was greater for all months and most water years at both facilities, supported by results from the two quantitative models.

Potential Changes to Routing of Spring-run Chinook Salmon

ECO-PTM

Differences in flows under Alternative 4 compared with the No Action Alternative may have effects on juvenile Chinook salmon's routing to Interior Delta via Georgiana Slough in the Delta. This possible difference was evaluated using ECO-PTM, a quantitative model. Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under Alternative 4 ranged from less than the No Action Alternative (up to 7% less under <-5,500 cfs) to greater than the No Action Alternative (up to 12% greater under -3,500 cfs) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in the attachment. The decrease in routing to the Interior Delta could have a beneficial effect on outmigrating juveniles while the increase in routing could have an adverse effect on outmigrating juveniles. For a detailed description of how flows under Alternative 4 may impact spring-run Chinook salmon routing, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2).

Summary

Alternative 4 relative to the No Action using ECO-PTM suggest a potential adverse or beneficial impact dependent on OMR grouping due to differences in flow.

Potential Changes to Through Delta Survival of Spring-run Chinook Salmon

ECO-PTM

Differences in flows under Alternative 4 compared with the No Action Alternative may have effects on juvenile Chinook salmon's through-Delta survival. This possible difference was evaluated using ECO-PTM, a quantitative model. Mean through-Delta percent survival December through March under Alternative 4 ranged from less than the No Action Alternative (up to 5% less under -3,500 cfs) to greater than the No Action Alternative (up to 6% more under

<-5,500 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in the attachment. The increase in survival under some OMR conditions could have a beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have an adverse effect on outmigrating juveniles. For a detailed description of how flows under Alternative 4 may impact spring-run Chinook salmon through-Delta survival, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2).

Delta Passage Model

Under Alternative 4, in all water year types except below normal, predicted mean survival of spring-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). The change in mean predicted survival to Chipps Island in all water year types is less than or equal to ± .0.002.

Summary

Alternative 4 relative to the No Action Alternative is expected to have a possible adverse to beneficial impact on survival of outmigrating juvenile spring-run Chinook salmon dependent on model due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have an adverse or beneficial impact dependent on OMR grouping (ECO-PTM), or no impact (DPM).

O.7.10 California Central Valley Steelhead DPS

O.7.10.1 Sacramento River

Spawning and Egg Incubation

Steelhead mostly use the Sacramento River as a migratory corridor for reaching other tributaries to spawn. Data on steelhead spawning in the mainstem Sacramento River is limited and likely restricted to the area upstream of Red Bluff (National Marine Fisheries Service 2009a). No steelhead specific spawner surveys occur in the upper Sacramento River. Data from recent surveys for the four runs of Chinook salmon have found carcasses of *O. mykiss* but the majority are thought to be resident trout adults (Killam 2022). Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional 2-4 weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In the Sacramento River, estimated incubation timing based on spawning is December through June.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 4, differences in mean spawning WUA are generally similar to or slightly lower than (less than 0.6%) the No Action Alternative across all water year types (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 4 and the No Action Alternative is a 0.05% increase in wet water years. The largest reduction in estimated spawning habitat is a -0.6% decrease in below normal water year types.

The monthly median value of spawning WUA under Alternative 4 is similar to the No Action Alternative January through April (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are relatively similar in January through March. In April, the median values of spawning WUA are higher across all alternatives when compared to the other spawning months. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently lowest in April when compared to other spawning months (Table O-266). This results in lower spawning WUA results because the steelhead spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 4,000 to 7,000 cfs).

The results of suitable habitat analysis using the SIT LCM habitat models suggest that spawning habitat for steelhead in the upper Sacramento River may increase in April under all alternatives compared to the other spawning months (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*. Lack of consistent spawner estimates for steelhead prevented Reclamation staff from calculating spawner limitation ratios for this species.

The results of the two spawning habitat analyses based on CalSim 3 flows suggest that Alternative 4 may have a negligible (less than 0.6%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. Out of the four months of steelhead spawning, April has the highest estimated spawning WUA across all alternatives.

Redd Dewatering Analysis

The results for Alternative 4 show a substantial reduction in mean redd dewatering potential from wetter to drier water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation reflects flow conditions for the winter and early spring months when steelhead spawning and incubation occurs. During wet winters and springs, periodic storms and high runoff increase flow fluctuations, which tend to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. Mean redd dewatering potential is lower under Alternative 4 than the No Action Alternative, including a maximum reduction of 19.2% in dry water years. Other reductions are small, ranging from 2.0% for above normal years to 0.1% for critically dry water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). For individual month periods, median redd dewatering potential under Alternative 4 is highest for February spawning and lowest for April spawning (Attachment L.4, *Sacramento River Redd Dewatering Analysis*).

Overall, the results indicate that steelhead redd dewatering potential under Alternative 4 is lower or little different relative to the No Action Alternative in all water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis* Table 134 for Keswick Dam and Table 136 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 140 for Keswick Dam and Table 142 for RBDD. Full results of the analysis assessing the percent of

months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 170 for Keswick Dam and Table 172 for RBDD.

Results for the three analyses are summarized in Table O-48. Table O-48, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 45.5°F to 55°F successful spawning range analysis, there were three and zero month-water year type combinations (13.3% and 0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-48). There were zero combinations (0%) with unfavorable results at Keswick Dam and RBDD. For the 59.9°F pathogen virulence threshold, there were zero and two combinations (0% and 6.7%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were zero and one combinations (0% and 3.3%) with unfavorable results at Keswick Dam and RBDD, respectively. For the 45°F to 52°F range for optimal egg incubation, there were one and zero combinations (2.9% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were six and two combinations (17.1% and 5.7%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be positive water temperature-related effects and negative effects of Alternative 4 on steelhead spawning and egg incubation in the Sacramento River.

Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on steelhead spawning behavior and redd dewatering from sudden drops in flow. Redd surveys are occurring during the pulse flow period and redd dewatering has not been observed.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead spawning and egg incubation based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are expected to have a negligible increase and/or decrease on spawning habitat area and may decrease redd dewatering potential during some water year types. There may be adverse impacts to spawning behavior from spring pulse flows. There may be redd dewatering following spring pulse flow events, though this has not been observed during redd surveys. The water temperature analysis indicates that there would be both beneficial and adverse impacts of Alternative 4 on steelhead spawning and egg incubation in the Sacramento River. Water temperatures outside the successful spawning range are expected to decrease in frequency under Alternative 4 relative to the No Action Alternative below Keswick Dam. Water temperatures outside of the optimal egg incubation range are expected to increase in frequency under Alternative 4 relative to the No Action Alternative below Keswick Dam.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in

the Sacramento River. The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station at Knight's Landing indicate outmigration into the Delta, with median passage starting in January and ending in May from 2006-2024 (Columbia Basin Research, University of Washington 2024).

Potential Changes to Steelhead from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 4, mean fry rearing WUA increases in critically dry water year types and decreases in all other water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). WUA curves were not developed for steelhead, so the late fall-run Chinook salmon curves were used to quantify spring-run habitat. The largest increase in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 3.9% increase in critically dry water year types. The largest reduction in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 0.8% decrease in below normal water year types.

The monthly median value of fry rearing WUA under Alternative 4 has a 7% reduction in September in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The median values are similar throughout the other fry rearing months. The estimated fry rearing WUA values under the modeled alternatives are highly variable across the months, April through October, but are generally highest in April and October (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). WUA values of the fry rearing WUA curve are lowest in the range of approximately 7,000 cfs to 13,000 cfs in Segment 5 (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and flows in this range are more frequent during May through August (Table O-266).

The results of the steelhead fry rearing habitat analysis based on CalSim 3 flows suggest that Alternative 4, in comparison to the No Action Alternative, may have a minor (less than 4%) increase and/or decrease in estimated fry rearing habitat across all water year types. There are some differences in estimated rearing WUA habitat under Alternative 4 when looking at a monthly scale, with a minor (7%) reduction in estimated fry rearing habitat in September in comparison to the No Action Alternative.

Juvenile Rearing Habitat Analyses

Under Alternative 4, differences in mean juvenile rearing WUA constitute reductions in all water year types in comparison to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The upper and lower limits of the range in WUA values are determined by the ranges of the juvenile rearing WUA curves for late-fall run since there were no reliable WUA curves for steelhead (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The analysis includes all months because steelhead juveniles may reside in freshwater for a year or more before emigrating to the ocean. There are no increases in estimated juvenile rearing habitat under Alternative 4 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 4 and the No Action Alternative is a 1.2% decrease in below normal water year types.

The monthly median values of juvenile rearing WUA under Alternative 4 are similar to the No Action Alternative throughout the year (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The juvenile rearing WUA values under the modeled alternatives are similar December through March, and gradually decrease until the lowest estimated values in July. The high WUA values with low variability in the third quartile for December through March result from the peaking of the WUA curve at the lowest flows (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and frequent low Keswick Dam flow releases during these months to build Shasta Reservoir storage (Table O-266). The wide range of values in the first quartile of these months reflects the high frequency and variability of higher flows in these wet months. The low juvenile rearing WUA values June through August result from releases in the summer months above 10,000 cfs and estimated peak juvenile rearing at flows below 5,000 cfs.

The results of the suitable habitat analysis using the SIT LCM habitat models indicate that steelhead juvenile instream rearing habitat in the upper Sacramento River have a 3.9% to –3.0% difference from January through December (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest increase in estimated habitat may occur in September and the greatest reduction in estimated habitat may occur in November under Alternative 4 in comparison to the No Action Alternative.

The results of the two steelhead juvenile rearing habitat analyses based on CalSim 3 flows suggest that Alternative 4, in comparison to the No Action Alternative, may have a minor (less than 2%) decrease in estimated steelhead juvenile rearing habitat across all water year types and that the greatest increase in estimated habitat may occur in September (3.9%) in the mainstem upper Sacramento River.

Fry Stranding Analysis

The analysis of fry stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Mean stranding of steelhead fry under Alternative 4 shows large variation among water year types, with wet years having the highest stranding and dry water years the lowest (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Alternative 4 shows the highest stranding in February, with the median level trending down over the next three months (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher mean stranding levels for steelhead fry during February and wet water year types likely results because of periodic storms and high runoff that produce increased variability of flow. Steelhead fry rearing occurs primarily during late winter and spring. Mean stranding under Alternative 4 is lower than stranding under No Action Alternative for all water year types, including a reduction of 23.4% for dry water years. Reduction in other water year types range from 9.4% in critically dry years to 1.3% in above normal water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, mean stranding for steelhead fry is lower under Alternative 4 than under the No Action Alternative, including an especially large reduction for dry water year types.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperature range year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 182 for Keswick Dam and Table 184 for

RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 188 for Keswick Dam, Table 190 for Red Bluff Diversion Dam, and Table 192 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 55°F upper limit of successful smoltification during January through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 196 for Keswick Dam, Table 198 for Red Bluff Diversion Dam, and Table 200 for Hamilton City.

Results for the three analyses are summarized in Table O-49. Table O-49, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 66.2°F upper limit of optimum temperature range, there were zero and one month-water year type combinations (0% and 1.7% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-49). There were no combinations (0%) with unfavorable results at both locations. For the 59.9°F juvenile pathogen virulence threshold, there were one and seven combinations (1.7% and 11.7%, respectively) with favorable results depending on location. There were zero and three combinations (0% to 5.0%) with unfavorable results depending on location. For the 55°F upper limit of successful smoltification, there were zero to three combinations (0% to 12.0%) with favorable results depending on location. There were no combinations (0%) with unfavorable results depending on location. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 4 on steelhead juvenile rearing and emigration in the Sacramento River.

<u>Sacramento River Pulse Flows</u>

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

<u>Summary</u>

There are expected generally beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are expected to have a minor increase and/or decrease on fry and juvenile rearing habitat area. Changes in flows are expected to decrease fry stranding, with moderate decreases during dry water year types. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. Water temperatures above the smoltification upper limit are expected to decrease in frequency below Keswick Dam. The frequency of exceedance above the pathogen virulence threshold is expected to increase, decrease, or remain unchanged, depending on location, under Alternative 4 compared to the No Action Alternative.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). Historical data at the Fremont Weir have shown that adult steelhead migrate upstream in the Sacramento River during most months of the year, beginning in July, peaking in September, and continuing through March (Hallock 1989; McEwan 2001; Hallock et al. 1957).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

A flow threshold of 3,250 cfs has been used to evaluate the potential for adverse effects on steelhead migrating and holding adults in the Sacramento River (Bureau of Reclamation 2019). Flows in the Sacramento River rarely drop below this level, and adults have not been observed to experience passage delays, crowding, or other adverse effects at this flow. Therefore, it represents a reasonable threshold for evaluating the potential for adverse effects on migrating and holding adults.

During the steelhead adult upstream migration and holding period, CalSim 3 modeling of Sacramento River mean monthly flows at Wilkins Slough indicate that flows are expected to go below the minimum flow in September of critically dry water year types under the No Action Alternative but flows are expected to have a minor (3%) increase under Alternative 4 (Table O-268). Flows in the Sacramento River at Wilkins Slough range from about 3,250 cfs in September of critically dry water years to about 19,900 cfs in February of wet water years during the adult migration period. Flows in the Sacramento River at RBDD range from about 5,200 cfs in October of critically dry water years to almost 37,000 cfs in February of wet water years during the adult migration period (Table O-267). Under Alternative 4, Reclamation will operate minimum instream flows at 2,300 cfs in March, July, and August, and 3,250 cfs from September through February but the schedule may change in critically dry water years (WRO Order 90-5). Since peak adult migration occurs around September, there may be minor beneficial effects to adult steelhead in September of critically dry years if flows are reduced in the lower Sacramento River under Alternative 4.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range for minimal migration impairment during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 110 for Keswick Dam, Table 112 for Red Bluff Diversion Dam, and Table 114 for Hamilton City. Results for the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 118 for Keswick Dam, Table 120 for Red Bluff Diversion Dam, and Table 122 for Hamilton City. Results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for adult migration and holding during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 126 at Keswick Dam, Table 128 for Red Bluff Diversion Dam, and Table 130 for Hamilton City.

Results for the three analyses are summarized in Table O-50. Table O-50, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 41°F to 66.2°F range for minimal migration impairment, there were zero to one month-water year type combinations (0% to 2.2% of total combinations during the period) with favorable results depending on location (Table O-50). There were also zero to one month water-year type combinations (0% to 2.2%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at any location. There were no combinations (0%) with unfavorable results depending on location. For the 59.9°F adult migration pathogen virulence threshold, there were zero to five combinations (0% to 11.1%) with favorable results depending on location. There were zero to one combinations (0% to 2.2%) with unfavorable results depending on location. These results suggest that there would be positive water temperature-related effects and negligible negative effects of Alternative 4 on steelhead adult upstream migration and holding in the Sacramento River.

Sacramento River Pulse Flows

There may be beneficial impacts of spring pulse flows on adult migration through decreased travel time.

Summary

There are expected beneficial impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 4 compared to the No Action Alternative. Under Alternative 4, changes in flows are expected to have a negligible impact in the upper portions of the Sacramento River but may have a minor beneficial impact during peak migration in September of critically dry water year types, in the lower Sacramento River below Wilkins Slough. Spring pulse flow events may decrease travel time for adult migrants. Alternative 4 would primarily improve water temperature conditions for migrating and holding steelhead adults in the Sacramento River.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Similar to the section above for adult migration, a threshold of 3,250 cfs has been used to evaluate the potential for adverse effects (Bureau of Reclamation 2019). Flows in the Sacramento River rarely drop below this level, and adults have not been observed to experience passage delays, crowding, or other adverse effects at this flow. Therefore, it represents a reasonable threshold for evaluating the potential for adverse effects on migrating and holding adults.

During the steelhead kelt emigration period, approximately February through June, CalSim 3 modeling of Sacramento River mean monthly flows do not go below the threshold of 3,250 cfs at Keswick Dam, RBDD, Wilkins Slough or Hamilton City under Alternative 4 and the No Action Alternative (Table O-266 through Table O-269). These results suggest flows are adequate for kelt emigration in the Sacramento River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F migration impairment limit during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 146 for Keswick Dam, Table 148 for Red Bluff Diversion Dam, and Table 150 for Hamilton City. Full results for the percent of months with water temperature above the 69.8°F lethal limit to kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 154 for Keswick Dam, Table 156 for Red Bluff Diversion Dam, and Table 158 for Hamilton City. Full results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 162 for Keswick Dam, Table 164 for Red Bluff Diversion Dam, Table 166 for Hamilton City.

Results for the three analyses are summarized in Table O-51. Table O-51, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 66.2°F migration impairment limit, there were zero to three month water-year type combinations (0% to 12.0%) with favorable results depending on location (Table O-51). There were zero to one combination (0% to 4.0%) with unfavorable results depending on location. For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with favorable results at all locations. There were no combinations (0%) with unfavorable results depending at all locations. For the 59.9°F adult migration pathogen virulence threshold, there were zero to two combinations (0% to 8.0%) with favorable results depending on location. There were zero to two combinations (0% to 8.0%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 4 on steelhead kelt emigration in the Sacramento River.

Sacramento River Pulse Flows

There may be beneficial impacts of spring pulse flows on kelt emigration through decreased travel time.

Summary

There are expected negligible impacts of seasonal operations on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are expected to be above the minimum flow to avoid crowding and passage delays from Keswick Dam to Hamilton City in the Sacramento River. Spring pulse flow events may decrease travel time for kelt emigration. Alternative 4 would cause beneficial and adverse water temperature-related impacts to emigrating kelts in the Sacramento River.

O.7.10.2 Clear Creek

Spawning and Egg Incubation

In Clear Creek, the temporal distribution of redd count data shows spawning December through April, with peak spawning January (Schaefer et al. 2019; Provins and Chamberlain 2019a, 2019b, 2020). Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional 2-4 weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In Clear Creek, estimated incubation timing based on spawning is late-December through late-May.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

Under Alternative 4, mean spawning WUA increases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The greatest increase in estimated spawning habitat is a 7.3% increase in dry water year types under Alternative 4 in comparison to the No Action Alternative. There are no anticipated reductions in mean spawning WUA under Alternative 4 in comparison to the No Action Alternative.

The mean values of spawning WUA by month are higher under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The four months of spawning are expected to have similar spawning WUA values.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that steelhead spawning habitat under Alternative 4 may have a minor decrease (1.0%) in January and March, and a minor increase (4.2%) in February in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

The two spawning habitat analyses based on CalSim 3 flows suggest that Alternative 4 may have a beneficial effect (up to 7.3% increase) in steelhead spawning habitat in Clear Creek across all water year types when compared to the No Action Alternative, and that spawning habitat will likely have a minor decrease in January/March and minor increase in February on a monthly scale in Clear Creek.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis* Table 138 for Clear Creek at Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during December through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 144 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 174 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-52. Table O-52, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 45°F to 55°F range for successful spawning, there was one month-water year type combinations (3.3% of total combinations during the period) with both favorable and unfavorable results below Whiskeytown Dam (Table O-52). For the 59.9°F adult pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 45°F to 52°F range for optimal egg incubation, there was one combination (2.9%) with favorable results and two combinations (5.7%) with unfavorable results below Whiskeytown Dam. These results suggest that there would be similar positive and negative water temperature-related effects of Alternative 4 on steelhead spawning and egg incubation in Clear Creek.

Summary

There are expected minor to moderate beneficial impacts of seasonal operations on steelhead spawning and egg incubation based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows may have a beneficial impact on spawning habitat area across all water year types. Water temperatures outside of the optimal egg incubation range are expected to have similar increases and decreases in frequency overall in Clear Creek below Whiskeytown Dam.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in Clear Creek. The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station in lower Clear Creek indicates outmigration into the Sacramento River with median passage starting in November and ending in June, with peak passage between April and June (Schraml and Chamberlain 2019a, 2019b, 2020, 2021).

Potential Changes to Steelhead from Seasonal Operations

Fry Rearing Habitat Analysis

Under Alternative 4, mean fry rearing WUA decreases in critically dry water year types and increases in all other water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 1.3% increase in dry water year types. The only decrease in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 0.2% decrease in critically dry water year types.

The mean values of fry rearing WUA by month are slightly higher March through May and slightly lower February and June under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The five fry rearing months are expected to have similar fry rearing WUA values.

The results of the fry rearing habitat analysis suggest that Alternative 4 may have a negligible (less than 1.3%) increase and/or decrease in estimated steelhead fry rearing habitat across all water year types in Clear Creek.

Juvenile Rearing Habitat Analyses

Under Alternative 4, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 4 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 4 and the No Action Alternative is a 5% decrease in dry water year types. On average across all water year types, there is a 4.4% reduction in estimated juvenile rearing habitat under Alternative 4.

The mean values of juvenile rearing WUA by month are lower July through October and higher in November and December under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the six months, December is expected to have the highest juvenile rearing WUA values under Alternative 4.

The results of suitable habitat analysis using the SIT LCM habitat models indicate that instream juvenile rearing habitat for steelhead in Clear Creek may decrease 1.2-15.0% in February and June through October and may increase 5.8-10.4% November through January and March through May under Alternative 4 in comparison to the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). The greatest decrease in estimated juvenile rearing habitat may occur in June and the greatest increase in juvenile rearing habitat may occur in May.

The results of the two steelhead juvenile rearing habitat analyses based on CalSim 3 flows suggest that Alternative 4 may have a minor to moderate adverse effect, as rearing habitat may decrease 4.4% on average across all water year types in comparison to the No Action Alternative, and may increase and decrease throughout the year on a monthly scale. The steelhead juvenile rearing WUA analysis in Attachment O.1, *Clear Creek Weighted Usable Area Analysis* analyzed the period between July and December, but some juveniles may rear year-round in Clear Creek, up to four years before emigration to the ocean. The greatest decrease in estimated juvenile

rearing habitat may occur in July and the greatest increase in juvenile rearing habitat may occur in May.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperature range year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 186 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 194 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 55°F upper limit of successful smoltification during January through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 202 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-53. Table O-53, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 66.2°F upper limit of optimum water temperature range for juvenile steelhead growth, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-53). For the 59.9°F juvenile pathogen virulence threshold, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 55°F upper limit of successful smoltification, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on juvenile steelhead rearing and emigration in Clear Creek.

Summary

There are expected adverse impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are expected to have a decrease in juvenile rearing habitat area across all water year types. Water temperatures above the juvenile optimum temperature and pathogens and disease criteria are expected to slightly increase in frequency in Clear Creek below Whiskeytown Dam under Alternative 4.

Adult Upstream Migration and Holding

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the period of adult steelhead migration and holding in Clear Creek, the mean monthly flows under Alternative 4 compared to the No Action Alternative are on average reduced August through October and increased November through January (Table O-275). Throughout the full simulation period, flows on average will range from roughly a 36% increase to 31% reduction

under Alternative 4. Flows are expected to generally be above 100 cfs throughout this period in Clear Creek, and unlikely to cause delays in migration and crowding for adult steelhead.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range for minimal migration impairment during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 116 for below Whiskeytown Dam. Results for the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 124 for below Whiskeytown Dam. Results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for adult migration and holding during July through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 32 for below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-54. Table O-54, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 41°F to 66.2°F range for minimal migration impairment, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-54). For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F pathogen virulence threshold for adult migration, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be no anticipated water temperature-related effects of Alternative 4 on steelhead adult upstream migration and holding in Clear Creek.

Summary

There are anticipated minor adverse impacts of seasonal operations on adult steelhead based on analyses of simulated flows and water temperature under Alternative 4 in comparison with the No Action Alternative. Under Alternative 4 compared to the No Action Alternative, Clear Creek flows are likely adequate for migrating adults. There are no anticipated water temperature-related effects of Alternative 4 relative to the No Action Alternative.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During the period of steelhead kelt emigration in Clear Creek, the mean monthly flows under Alternative 4 compared to the No Action Alternative will be reduced towards the tail ends of emigration and increased during peak emigration (Table O-275). Throughout the full simulation period, flows on average will have a 10% reduction in February and a 31% reduction in June under Alternative 4. Throughout the full simulation period, flows on average will have a 15-36% increase March through May under Alternative 4. Flows are above 100 cfs in Clear Creek throughout this period under Alternative 4. These results suggest there are negligible effects of flow to steelhead kelt emigration under Alternative 4.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F migration impairment limit during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 152 for below Whiskeytown Dam. Full results for the percent of months with water temperature above the 69.8°F lethal limit to kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 160 for below Whiskeytown Dam. Full results for the percent of months with water temperature above the 59.9°F pathogen virulence threshold for kelt emigrants during February through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 168 for below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-55. Table O-55, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 66.2°F kelt migration impairment limit, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-55). For the 69.8°F upper lethal limit to adult migrants, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F pathogen virulence threshold for adult migration, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible effects of Alternative 4 on steelhead kelt migration in Clear Creek.

Summary

There are anticipated negligible impacts of seasonal operations on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 4 in comparison with the No Action Alternative. Under Alternative 4, flows are likely adequate for the small proportion of the population that emigrate as kelts in Clear Creek. Water temperatures above the three temperature criteria for kelts are not anticipated to change in frequency in Clear Creek below Whiskeytown Dam under Alternative 4 in comparison to the No Action Alternative.

O.7.10.3 Lower American River

Spawning and Egg Incubation

In the lower American River, redd surveys have reported spawning January through mid-April, with peak spawning in February (Sweeney et al. 2021). The median months of spawning from 2002-2021 were from January through March. Redd surveys on the lower American River do not occur until the first week of January, and there are reports from the Sacramento Water Forum (2015) that indicate spawning starts in late December. Therefore, the timing window of spawning on the lower American River was analyzed from late December until March.

Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional 2-4 weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). On the lower American River, egg incubation starts in late December and ends in late May, with peak incubation between February and April (Hannon pers. comm. 2023; Sacramento Water Forum 2015).

Potential Changes to Steelhead from Seasonal Operations

<u>Spawning Habitat—Flow Analyses</u>

Under Alternative 4, lower American River steelhead mean spawning WUA is highest in critically dry water years and falls sharply with wetter year types (Attachment M.3, *American River Weighted Usable Area Analysis*). This pattern of variation occurs because streamflow during the January through March spawning season of steelhead rises from dry to wetter water year types (Table O-277). The lower American River steelhead spawning WUA curve peaks at about 2,000 cfs (Attachment M.3, *American River Weighted Usable Area Analysis*) and flows under Alternative 4 are consistently well above this level in the wetter water years. February flows are especially high in all but critically dry water years and consequently February shows the lowest spawning WUA for all alternatives (Attachment M.3, *American River Weighted Usable Area Analysis*). Differences in mean spawning WUA between Alternative 4 and the No Action Alternative are small, ranging from 2.9% lower for dry water years to no change for wet years. Median spawning WUA under Alternative 4 is about the same as that under the No Action Alternative for all the three months of the spawning season (January through March) (Attachment M.3, *American River Weighted Usable Area Analysis*).

The results of the SIT LCM model for Alternative 4 show a decrease in spawning habitat (-3.5 to 5.7% changes) in comparison to the results for the No Action Alternative (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

Overall, the results indicate that there is little difference in mean spawning WUA for steelhead between Alternative 4 and the No Action Alternative.

Redd Dewatering Analysis

The results of the analysis for redd dewatering potential under Alternative 4 for lower American River steelhead indicate that redd dewatering is much greater in wetter water years than in drier water years (Attachment M.1, *American River Redd Dewatering Analysis*). This difference reflects the greater frequency of larger flow fluctuations in wetter years. Mean steelhead redd dewatering potential is similar or higher under Alternative 4 than under the No Action Alternative for all water year types, ranging from 0.2% lower in wet water years to 132.7% higher in critically dry water years. Redd dewatering is also much higher under Alternative 4 in dry and below normal water years, with 62.4% and 12.7% increases, respectively (Attachment M.1, *American River Redd Dewatering Analysis*). The magnitude of these changes may be somewhat misleading: in absolute terms, the increases range from 2.3% to 6.1%. For the individual months of steelhead spawning in the lower American River, median redd dewatering potential is highest and variability is greatest in February for both the No Action Alternative and Alternative 4 (Attachment M.1, *American River Redd Dewatering Analysis*). This occurs because flows during the two-month incubation period following February spawning exhibit greater declines than those for January and March (Table O-277). The median for February spawning under Alternative 4 is much higher than that under the No Action Alternative (Attachment M.1, *American River Redd Dewatering Analysis*).

Overall, the results indicate that Alternative 4 produces substantial increases in redd dewatering potential of steelhead relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 20 for Hazel Avenue and Table 22 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold for spawning adults during December through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 24 for Hazel Avenue and Table 26 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 40 for Hazel Avenue and Table 42 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold during December through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 44 for Hazel Avenue and Table 46 for Watt Avenue.

Results for the analysis are summarized in Table O-56. Table O-56 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 45°F to 55°F range for successful spawning there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-56). There were three and one month-water year type combination (15% and 5%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the

59.9°F spawning pathogen virulence threshold, there were zero combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue. For the 45°F to 52°F range for optimal egg incubation there were there were one and zero month-water year type combinations (3.3% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were two and zero month-water year type combinations (6.7% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold, there were there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue, respectively. There was one month-water year type combinations (3.3%) with unfavorable results at both Hazel Avenue and Watt Avenue. These results suggest that Alternative 4 would have unfavorable water temperature-related effects (3.3% to 15%) to steelhead spawning and egg incubation in the lower American River.

Summary

There are expected minor adverse and substantial beneficial impacts of seasonal operations on steelhead spawning and egg incubation in the lower American River based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are expected to have a minor decrease on spawning habitat area and are expected to substantially increase redd dewatering potential. Alternative 4 is expected to increase the frequency of unfavorable conditions for steelhead spawning and egg incubation by up to 15% in the lower American River compared to the No Action Alternative.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Yearling rearing is year-round in the lower American River. Young of the year fry rearing is from February through May (Sacramento Water Forum 2015). The timing of juvenile outmigration depends on the watershed and water year. The RST monitoring station in the lower American River indicates outmigration into the Sacramento River with median passage starting in January and ending in May, with peak passage between March and May (Day 2022a).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

During steelhead rearing in the lower American River, the mean monthly flows under Alternative 4 compared to the No Action Alternative are reduced in the late summer, fall, and spring under critically dry water year types, which may reduce their rearing habitat (Table O-278, Table O-277). Reductions under Alternative 4 are anticipated in August through October and February through May of critically dry water year types. The greatest increase in flows under Alternative 4 occurs in July of a critically dry water year type (16% in the lower American River at H St). The greatest reduction occurs in March of a critically dry water year type (24% in the lower American River at H St). Throughout the full simulation period, flows on average are similar (less than 7% difference) under Alternative 4 compared to the No Action Alternative.

The CalSim 3 simulated flow results suggest that changes in flow in the lower American River under Alternative 4 compared to the No Action Alternative may have an adverse effect on both juvenile and fry rearing habitat during critically dry water year types. There are no reliable estimates for steelhead juvenile rearing habitat using weighted usable area analyses. U.S. Fish and Wildlife Service (1985) derives spawning and rearing weighted usable area on fall-run Chinook salmon, but this study did not assess steelhead and has not been peer reviewed.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 48 for Hazel Avenue and Table 50 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F rearing and outmigration pathogen virulence threshold year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 52 for Hazel Avenue and Table 54 for Watt Avenue. Full results of the analysis assessing water temperatures above the percent of months with water temperature above the 55°F limit of successful smoltification during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 56 for Hazel Avenue and Table 58 for Watt Avenue.

Results for the analysis are summarized in Table O-57. Table O-57 the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 66.2°F upper limit of optimum temperatures for juvenile steelhead growth, assuming maximum ration levels, there were four and one month-water year type combinations (6.7% and 1.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-57). There were two and four month-water year type combinations (3.3% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F juvenile rearing and outmigration pathogen virulence threshold, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There was one month-water year type combinations (1.7%) with unfavorable results at both Hazel Avenue and Watt Avenue,. For the 55°F limit of successful smoltification, there were zero and one month-water year type combinations (0% and 4%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and one month-water year type combinations (0% and 4%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be positive (1.7% to 6.7% favorable) and negative (1.7% to 6.7% unfavorable) water temperature-related effects to steelhead juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration in the lower American River based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4 in critically dry water year types, reductions in flows may decrease rearing habitat area. Water temperatures above the optimum juvenile growth criteria increase and decrease in frequency and temperatures above the smoltification criteria increase and decrease in frequency at Hazel Ave and Watt Ave.

Adult Upstream Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). In the lower American River, adult steelhead migration may occur as early as July and through early April, with peak abundance in January and February (Sacramento Water Forum 2015; Hallock 1989; Hallock et al. 1957).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Flows in the lower American River below Nimbus Dam are expected to be adequate during peak adult migration and holding under Alternative 4 compared to the No Action Alternative (Table O-277 and Table O-278). Peak steelhead adult migration in the lower American River occurs between January and February (Sacramento Water Forum 2015), when flows are expected to be less than a 11% increase or decrease under Alternative 4 across all water year types (Table O-277 and Table O-278). The largest reductions in flow under Alternative 4 for adult migration occur in March of critically dry water year type. The largest increases in flow under Alternative 4 occur in July of a critically dry water year type. Flows in September and October of critically water year types are expected to be below 1,000 cfs under Alternative 4 but are likely still adequate for adult migration (Table O-278). Throughout the full simulation period, flows on average are similar (less than 5% difference) under Alternative 4 compared to the No Action Alternative.

These results of the CalSim 3 simulated flows suggest that there may be a negligible effect of Alternative 4 compared to the No Action Alternative on steelhead adult migration and holding in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range of minimal migration impairment for adult steelhead during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 8 for Hazel Avenue and Table 10 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through April are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 12 for Hazel Avenue and Table 14 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult upstream migration and holding pathogen virulence threshold during July through April are presented in Attachment M.2,

American River Water Temperature Analysis, Table 16 for Hazel Avenue and Table 18 for Watt Avenue.

Results for the three analyses are summarized in Table O-58. Table O-58 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 41°F to 66.2°F range of minimal migration impairment for adult steelhead under Alternative 4, there were four and one month-water year type combinations (8% and 2%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-58). There were two and one month-water year type combinations (4.0% and 2.0%, respectively%) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F upper lethal limit to adult migrants, there was one month-water year type combination (2.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were one and three month-water year type combinations (2.0% and 6.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F adult upstream migration and holding pathogen virulence threshold, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero and one month-water year type combinations (0.0% and 2%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that there would be positive (2% to 8% favorable) and negative (2% to 6% unfavorable) water temperature-related effects to steelhead adult upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue.

<u>Summary</u>

There are expected beneficial impacts of seasonal operations on adult steelhead based on analyses of simulated flows under Alternative 4 in comparison with the No Action Alternative. Under Alternative 4 compared to the No Action Alternative, there are likely adequate flows during peak adult migration and holding. Water temperatures outside the range of minimal migration impairment increase and decrease in frequency in the lower American River under Alternative 4 compared to the No Action Alternative.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, the timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Flows in the lower American River below Nimbus Dam are expected to be adequate during peak kelt emigration under Alternative 4 compared to the No Action Alternative (Table O-277 and Table O-278). The largest reductions in flow under Alternative 4 during kelt emigration occur in March of critically dry water year types. The largest increases in flow under Alternative 4 occur in May of dry water year types. Throughout the full simulation period, flows on average are similar (less than 5% difference) under Alternative 4 compared to the No Action Alternative.

These results of the CalSim 3 simulated flows suggest that there may be a negligible effect of Alternative 4 compared to the No Action Alternative on steelhead kelt emigration in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F limit of migration impairment for steelhead kelt emigration during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 28 for Hazel Avenue and Table 30 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F lethal limit for steelhead kelt emigration during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 32 for Hazel Avenue and Table 34 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F kelt emigration pathogen virulence threshold during February through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 36 for Hazel Avenue and Table 38 for Watt Avenue.

Results for the three analyses are summarized in Table O-59. Table O-59 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F limit of migration impairment for steelhead kelt emigration under Alternative 4, there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-59). There were zero and three month-water year type combinations (0.0% and 12.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 69.8°F lethal limit for steelhead kelt emigration there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue. For the 59.9°F kelt emigration pathogen virulence threshold there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were three and five month-water year type combinations (12.0% and 20.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. These results suggest that there would be negative (4% to 12% unfavorable) water temperature-related effects to steelhead kelt emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There are expected negligible impacts of seasonal operations on steelhead kelt emigration based on analyses of simulated flows under Alternative 4 in comparison with the No Action Alternative. Under Alternative 4 compared to the No Action Alternative, there are likely adequate flows for kelt emigration. Water temperatures above the three temperature criteria increase in frequency (4-12%) or remain unchanged (0%) in the lower American River under Alternative 4 in comparison to the No Action Alternative.

O.7.10.4 Bay-Delta

Juvenile Rearing and Emigration

While juvenile steelhead can be found in all waterways of the Delta, they are seen more frequently in the main channels to their natal river systems (National Marine Fisheries Service 2009a). The San Francisco Estuary is used as a short-term outmigration corridor for juvenile steelhead but the propensity of rearing in the Delta is currently unknown (Hayes and Kocik 2014, Chapman et al. 2015, Buchanan et al. 2021). The USFWS monitoring programs (Sacramento beach seines, Sacramento trawl, and Knight's Landing RST) indicate outmigration timing from the Sacramento River with first median passage in January and last median passage in May (Columbia Basin Research, University of Washington 2024). Outmigration from the San Joaquin River is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024).

Potential Changes to Steelhead from Seasonal Operations

Zone of Influence

Differences in hydrology under Alternative 4 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. With incremental decreases in OMR under Alternative 4 and the No Action Alternative, proportional overlap at these three locations decreases, with more subtle changes along the San Joaquin River at Jersey Point compared to Turner Cut and Old River at Middle River. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under Alternative 4 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2, *Zone of Influence*).

Flow into Junctions

Differences in flow routing under Alternative 4 compared with the No Action Alternative may have effects on the flow into the Head of Old River and CVP junctions.

Under Alternative 4 in all OMR bins except -3,500, predicted proportion of flow entering the Central Valley Project is less than the No Action Alternative. Changes in predicted proportion of flow entering the CVP in OMR bins -3,500, -5,000, and <-5,500 was less than ± 0.0372, indicating a negligible difference between Alternative 4 and the No Action Alternative. However, in OMR bin -2,000 the change in predicted proportion of flow into CVP was -0.0676 indicating

that slightly less flow will be routed into CVP under Alternative 4 than when compared to the No Action Alternative.

Under Alternative 4 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the HOR is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.026, indicating a negligible difference between Alternative 4 and the No Action Alternative.

For a detailed description of how flows under Alternative 4 may impact the flow at HOR and CVP, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2, *Flow into Junctions*).

Summary

Alternative 4 relative to the No Action Alternative is expected to influence flow into the HOR and CVP junctions due to differences in water management. Under Alternative 4, no change to possibly less flow into CVP under OMR -2,000; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 4 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Steelhead

Salvage Density and Negative Binomial

Predictions from the salvage density and the negative binomial model for steelhead include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of steelhead at SWP Banks Pumping Plant for all the months December through April and all water year types Alternative 4 was lower than predicted average monthly loss under the No Action Alternative, with up to a 13% decrease in predicted loss for dry water year types (Table O-60). Predicted average monthly loss of steelhead at CVP Jones Pumping Plant for all the months October through April for Alternative 4 was lower than predicted average monthly loss under the No Action Alternative for wet, below normal, and dry water year types, with up to a 5% decrease in predicted loss for wet water year types. Predicted monthly loss at Jones for steelhead under Alternative 4 compared to the No Action Alternative increased for above normal, and dry water year types, with up to a 2% increase for both water year types (Table O-61). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Predicted average monthly salvage of juvenile steelhead at the Delta fish collection facilities for the months of December through June under Alternative 4 was higher than predicted loss under the No Action Alternative for all water year types, with up to a 60% increase for above normal water year types (Table O-62). For detailed information on average monthly salvage by water year type, see Attachment I.1, *Negative Binomial Model*.

Summary

The results of the two entrainment models suggest adverse and beneficial impacts of exports under Alternative 4 compared to the No Action Alternative, with increases and decreases in entrainment (depending on water year type) and the magnitude of changes varying between the two models. Alternative 4 relative to the No Action Alternative is expected to have a moderate to substantial increases in loss across all water year types (16-60%) on the entrainment of steelhead in the Delta at both fish facilities under the Negative Binomial model due to differences in exports. Alternative 4 relative to the No Action Alternative is expected to have minor to moderate decreases (1-13%) in steelhead loss across all water year types in the Delta at both fish facilities under the Salvage Density model due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have minor increases (2%) in steelhead loss in critically dry and above normal water year types at the CVP Jones Pumping Plant due to differences in flow.

Potential Changes to Routing and Through Delta Survival of Steelhead

ECO-PTM

Mean proportion of particles December through March routed to the Interior Delta, via Georgiana Slough, under Alternative 4 ranged from less than the No Action Alternative (up to 7% less under <-5,500 cfs) to greater than the No Action Alternative (up to 12% greater under -3,500 cfs) (Attachment I.7, *ECO-PTM*). Routing through other Delta-specific routes is discussed further in the attachment. The decrease in routing to the Interior Delta could have a beneficial effect on outmigrating juveniles while the increase in routing could have an adverse effect on outmigrating juveniles.

Mean through-Delta percent survival December through March under Alternative 4 ranged from less than the No Action Alternative (up to 5% less under -3,500 cfs) to greater than the No Action Alternative (up to 6% more under <-5,500 cfs) (Attachment I.7, *ECO-PTM*). Survival through Delta-specific routes is discussed further in the attachment. The increase in survival under some OMR conditions could have a beneficial effect on outmigrating juveniles while the decrease in survival under some OMR conditions could have an adverse effect on outmigrating juveniles.

For a detailed description of how flows under Alternative 4 may impact steelhead routing and through Delta survival, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2).

Summary

Alternative 4 relative to the No Action using ECO-PTM suggest a possible adverse or beneficial effect dependent on OMR grouping due to differences in flow.

O.7.10.5 San Joaquin River

Juvenile Emigration

The San Joaquin River is primarily documented as an outmigration corridor for juvenile steelhead (Buchanan et al. 2021). Outmigration from the San Joaquin River into the Delta is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024). RSTs in the lower Stanislaus River, a tributary to the San Joaquin River, suggests juvenile emigration into the San Joan Joaquin River starts in January and ends in June (Day 2022b).

Potential Changes to Steelhead from Seasonal Operations

Changes in flows from seasonal operations under Alternative 4 compared to the No Action Alternative may have a negligible effect on juvenile steelhead in the San Joaquin River. During the evaluated months in the juvenile emigration period, CalSim 3 estimates of mean monthly flows at Vernalis would generally be similar or increased under Alternative 4 compared to the No Action Alternative across all water year types (Table O-281). Throughout the full simulation period, average flows will range from 3,480 to 6,451 cfs under Alternative 4 during juvenile emigration.

Changes in water temperature from seasonal operations Alternative 4 compared to the No Action Alternative are likely to have a negligible effect on juvenile steelhead in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile emigration period (Figure O-15).

<u>Summary</u>

The results of these two simulation models suggest there are expected negligible impacts of seasonal operations on juvenile steelhead in the San Joaquin River under Alternative 4 relative to the No Action Alternative.

Adult Upstream Migration and Holding

Steelhead/rainbow trout of anadromous parentage occur at low numbers in all three major San Joaquin River tributaries. These tributaries have a higher percentage of resident rainbow trout compared to the Sacramento River and its tributaries (Zimmerman et al. 2009). Estimates of migrating adults in the San Joaquin River are made from the CDFW angler report cards and suggest that migration starts in July, peaks in December and January, and ends in March (California Department of Fish and Wildlife 2007).

Potential Changes to Steelhead from Seasonal Operations

Changes in flows from seasonal operations under Alternative 4 compared to the No Action Alternative may have a beneficial effect on adult steelhead migration and holding in the San Joaquin River in critically dry water year types. During the evaluated months in the adult migration period, CalSim 3 estimates of mean monthly flows at Vernalis would increase from July through September of critically dry water year types under Alternative 4 compared to the No Action Alternative (Table O-281). Throughout the full simulation period, average flows will range from 1,434 to 6,451 cfs under Alternative 4.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible effect on adult steelhead migration and holding in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the adult migration period (Figure O-15).

Summary

There are likely negligible to minor beneficial impacts of seasonal operations on adult steelhead migration and holding in the San Joaquin River based on analyses of simulated flows and water temperature under Alternative 4 in comparison with the No Action Alternative.

O.7.10.6 Stanislaus River

Spawning and Egg Incubation

Data on steelhead spawning in the Stanislaus River is limited, but adults appear to spawn primarily from January to April. In 2021, as part of the reasonable and prudent measure to accelerate steelhead monitoring and research in the National Marine Fisheries Service (2019) Biological Opinion, CDFW initiated the Stanislaus River Life Cycle Monitoring Program. Based on the initial redd survey report, which had a late start due to COVID-19 restrictions, spawning appears to start in February and last until April (Kok and Keller 2023). Although few steelhead spawning surveys have been conducted in the Stanislaus River, spawning *O. mykiss* has been documented upstream of the Highway 120 Bridge in Oakdale, between Goodwin Dam and the Oakdale Recreation Area.

Steelhead egg incubation varies with temperature and alevin typically hatch approximately 30 days post fertilization and remain in the gravel until the yolk sac is completely absorbed, for an additional two to four weeks (Shapovalov and Taft 1954, Reynolds et al. 1990, Sacramento Water Forum 2015). In the Stanislaus River, timing can only be estimated and would be January through late May.

Potential Changes to Steelhead from Seasonal Operations

Spawning Habitat—Flow Analyses

The spawning WUA results for Alternative 4 show consistent reductions in mean spawning WUA from drier to wetter water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the shape of the steelhead spawning WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show reduced WUA with increased flow, except at the lowest and highest flows (less than about 200 cfs and greater than about 800 cfs, respectively). CalSim 3 mean monthly flows below Goodwin Dam, which is immediately upstream of the WUA study reach, are 200 cfs or above in all water year types, with flow consistently increasing from critically dry to wet water years during all months of the December through April steelhead spawning period, except December (Table O-279). The mean spawning WUA estimates for Alternative 4 are below those for the No Action Alternative in all water year types, ranging from 1.2% lower in wet water years to 6.6% lower in below normal water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The spawning WUA results for individual months show much lower median spawning WUA under Alternative 4 relative to the No Action Alternative in December through March and higher

median spawning WUA in April (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results of the SIT LCM model for Alternative 4 are similar to those described above for spawning WUA regarding the magnitude of differences between Alternative 4 and the No Action Alternative, but the SIT analysis shows relatively more increases in spawning habitat under Alternative 4 while the WUA analysis shows reductions for all water year types and all months except April (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*).

Overall, the results of the WUA analysis indicate that mean spawning WUA for steelhead is lower under Alternative 4 than under the No Action Alternative, whereas the SIT analysis indicate that mean spawning habitat increases under Alternative 4 in all months except for January.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 55°F range for successful spawning during December through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 16 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence threshold for spawning adults during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 18 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 52°F range for optimal egg incubation during December through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 32 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 54°F index value for egg incubation during December through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 34 Full results of the analysis assessing the 59.9°F fry pathogen virulence threshold during December through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 36 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-63. Table O-63 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 45°F to 55°F range for successful spawning under Alternative 4, there were zero month-water year type combinations (0.0%) with favorable results and one month-water year type combination (3.3%) with unfavorable results at Orange Blossom Bridge (Table O-63). For the 59.9°F spawning pathogen virulence threshold, there were zero month-water year type combinations (0%) with favorable and unfavorable results at Orange Blossom Bridge. For the 45°F to 52°F range for optimal egg incubation analysis, there was one month-water year type combination (2.5%) with favorable results and two month-water year type combinations (5.0%) with unfavorable results at Orange Blossom Bridge. For the 59.9°F fry pathogen virulence threshold analysis, there were zero month-water year type combinations (0.0%) with favorable results and one month-water year type combination (2.5%) with unfavorable results at Orange Blossom Bridge.

These results suggest that Alternative 4 would have negligible effects on steelhead spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

There are expected minor adverse and minor beneficial impacts of seasonal operations on steelhead spawning and egg incubation in the Stanislaus River based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are expected to have a minor increase and/or decrease in spawning habitat area. Water temperatures outside the four spawning and egg incubation criteria are expected to have negligible increases in frequency the Stanislaus River at Orange Blossom Bridge.

Juvenile Rearing and Emigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. Juvenile rearing is year-round in the Stanislaus River. The timing of juvenile outmigration depends on the watershed and water year. RSTs in the lower Stanislaus River suggests juvenile emigration into the San Joan Joaquin River starts in January and ends in June (Day 2022b).

Potential Changes to Steelhead from Seasonal Operations

Rearing Habitat—WUA Analyses

The results for mean fry rearing WUA under Alternative 4 show general reductions from drier to wetter water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the steelhead fry WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show moderately reduced WUA with increased flow, especially in the Orange Blossom Bridge and Riverbank reaches, which are the longest segments. Mean fry rearing WUA under Alternative 4 is similar to or slightly higher than that for the No Action Alternative in all water year types. The differences range from 0.8% lower for critically dry water years to 3.2% higher for dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fry rearing period, median rearing WUA is higher under Alternative 4 than the No Action Alternative for April and similar for the other months (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

The results for juvenile rearing WUA under Alternative 4 show a minor increase in mean rearing WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in juvenile rearing WUA between Alternative 4 and the No Action Alternative are small, ranging from 0.2% higher for wet water years to 2.1% higher for critically dry water years. Juvenile rearing WUA is highest for Alternative 4 in February, April, and May (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in median rearing WUA between the Alternative 4 and the No Action Alternative are small in most months, but the median is lower for Alternative 4 in January and is much higher in February.

The SIT LCM model provides rearing habitat results for all juveniles, not separating out the fry stage from older juveniles. The instream juvenile rearing habitat results for Alternative 4 are similar to those described above for fry and juvenile rearing WUA, showing little difference in rearing habitat acreages between Alternative 4 and the No Action Alternative in all months,

except for a 5.6% increase for February (Attachment O.2, *CVPIA SIT LCM Habitat Estimates*). A large increase in February was also noted for the juvenile rearing WUA results above.

Overall, the rearing WUA results indicate that mean fry and juvenile rearing WUA for steelhead is largely similar under Alternative 4 to means under the No Action Alternative.

Rearing Habitat—ASH Analyses

The results of the Area of Suitable Habitat (ASH) analysis for fry and juvenile rearing for Alternative 4 show more variation in the means with the water year type than that found in the rearing WUA results described above. The ASH means consistently increase from drier to wetter water year types. This pattern of variation reflects the overall relationship between streamflow and ASH for both life stages determined from modeling and field studies (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in fry and juvenile ASH between Alternative 4 and the No Action Alternative are small, which is consistent with the results of the rearing WUA analyses. For fry rearing, the differences range from 2.6% lower for dry water years and to 1.2% higher for critically dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For juvenile rearing, the differences range from 0.3% lower for wet water years and to 2.0% higher for critically dry water years. For the individual months of the rearing periods, the median fry rearing ASH is similar between Alternative 4 and the No Action Alternative except in April, when the Alternative 4 median is lower. The median for juvenile rearing ASH is lower in January and April, higher in February, and roughly the same in the other months (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that steelhead fry and juvenile rearing ASH is largely similar under Alternative 4 relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F upper limit of optimal growth without food limitation year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 38 for Orange Blossom Bridge and Table 40 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 42 for Orange Blossom Bridge and Table 44 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperatures above the 55°F limit of successful smoltification during January through May are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 48 for Orange Blossom Bridge and Table 50 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-64. Table O-64 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F upper limit of optimal growth without food limitation under Alternative 4, there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-64). There were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 59.9°F juvenile pathogen virulence threshold, there were there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. There were one and three month-water year type combinations (1.7% and 5.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 55°F limit of successful smoltification, there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. There were one and zero month-water year type combinations (4.0% and 0.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 4 would have negligible water temperature-related effects on steelhead juvenile rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

There are expected adverse and beneficial impacts of seasonal operations on steelhead juvenile rearing and emigration based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are expected to have an increase and/or decrease in fry and juvenile rearing habitat area, depending on water year type. Water temperatures above the three juvenile rearing and emigration criteria are expected to have negligible increases in frequency in the Stanislaus River under Alternative 4.

Adult Upstream Migration and Holding

In the Stanislaus River, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as September and throughout March and can be recovered in the RST in Oakdale from November through April (Hellmair 2022; Eschenroeder et al. 2022).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Average flows in the Stanislaus River below Goodwin Dam are expected to be similar or increased during adult migration and holding under Alternative 4 compared to the No Action Alternative (Table O-279 and Table O-280). The largest reduction in flow is a 26% decrease under Alternative 4 in January of an above normal water year type. The largest increase in flow is a 45% increase under Alternative 4 in February of a dry water year type. Average flows are expected to be lowest in September and November under both the No Action Alternative and Alternative 4 during the adult migration and holding period. The major differences in these two months are a 17% increase in below normal water year types in September under Alternative 4. Throughout the full simulation period under Alternative 4 compared to the No Action

Alternative, flows on average increase (more than 5% difference) in December and February in the Stanislaus River below Goodwin Dam. Throughout the full simulation period under Alternative 4 compared to the No Action Alternative, flows on average increase (more than 5% difference) in July and August in the Stanislaus River below Goodwin Dam. The other adult migration months have similar flows (less than a 5% difference) in the Stanislaus River under Alternative 4.

These results of the CalSim 3 simulated flows suggest that there may be a minor beneficial effect of Alternative 4 compared to the No Action Alternative on steelhead adult migration and holding in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 41°F to 66.2°F range of minimal migration impairment for adult steelhead during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 4 for Orange Blossom Bridge and Table 6 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F upper lethal limit to adult migrants during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 8 for Orange Blossom Bridge and Table 10 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult upstream migration and holding pathogen virulence threshold during July through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 12 for Orange Blossom Bridge and Table 14 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-65. Table O-65 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 41°F to 66.2°F range of minimal migration impairment for adult steelhead, there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-65). There were also zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. For the 69.8°F upper lethal limit to adult migrants there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. For the 59.9°F adult upstream migration and holding pathogen virulence threshold there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River.

These results suggest that Alternative 4 would have negligible water temperature-related effects on steelhead adult upstream migration and holding in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

There are expected beneficial impacts of seasonal operations in the Stanislaus River on adult steelhead based on analyses of simulated flows and water temperature under Alternative 4 compared to the No Action Alternative. Under Alternative 4 compared to the No Action Alternative, there are potential beneficial impacts of increased flow in the fall of drier water year types for adult migration and holding. Water temperatures outside the range or above the adult migration and holding criteria are not anticipated to increase or decrease in frequency under Alternative 4 compared to the No Action Alternative.

Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013). Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, the timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008).

Potential Changes to Steelhead from Seasonal Operations

CalSim 3 Flows

Average flows in the Stanislaus River below Goodwin Dam are expected to be similar during kelt emigration under Alternative 4 compared to the No Action Alternative, with a minor increase in February and a minor decrease in April (Table O-279 and Table O-280). The largest reduction in flow is a 21% decrease under Alternative 4 in April of a below normal water year type, when flows under the No Action Alternative are 846 cfs. The largest increase in flow is a 45% increase under Alternative 4 in February of a dry water year type, when flows under the No Action Alternative are 200-250 cfs. Flows are expected to be lowest in March and February of drier water year types under the No Action Alternative and Alternative 4. The largest differences in these two months are 43-45% increases in February of dry and critically dry water year types under Alternative 4.

These results of the CalSim 3 simulated flows suggest that there are anticipated beneficial effects of Alternative 4 compared to the No Action Alternative on steelhead kelt emigration in the Stanislaus River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66.2°F limit of migration impairment for steelhead kelt emigration during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 20 for Orange Blossom Bridge and Table 22 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 69.8°F lethal limit for steelhead kelt emigration during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 24 for Orange Blossom Bridge and Table 26 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F kelt emigration pathogen virulence threshold during February through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 28 for Orange Blossom Bridge and Table 30 for above the confluence with the San Joaquin River.

Results for the three analyses are summarized in Table O-66. Table O-66 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 66.2°F limit of migration impairment for steelhead kelt emigration under Alternative 4, there were zero month-water year type combinations (0.0%) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-66). There were zero and two month-water year type combinations (0.0% and 8.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 69.8°F lethal limit for steelhead kelt emigration there were zero month-water year type combinations (0.0%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively. For the 59.9°F kelt emigration pathogen virulence threshold there were zero month-water year type combinations (0.0%) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River. There were one and three month-water year type combinations (4.0% and 12.0%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 4 would have negative water temperature-related effects to steelhead kelt emigration in the Stanislaus River.

Summary

There are expected minor beneficial and minor adverse impacts of seasonal operations in the Stanislaus River on steelhead kelts based on analyses of simulated flows and water temperature under Alternative 4 compared to the No Action Alternative. Under Alternative 4 compared to the No Action Alternative, there are potential minor beneficial impacts of flow for kelt emigration in drier water year types. Water temperatures above the limit of migration impairment and pathogens and disease threshold are expected to increase in frequency under Alternative 4 compared to the No Action Alternative.

O.7.11 Southern DPS Green Sturgeon

O.7.11.1 Sacramento River

Spawning and Egg Incubation

Southern DPS green sturgeon adults spawn primarily from April through July, although they periodically spawn in late summer and fall (as late as October). Northern DPS green sturgeon eggs hatch about a week after fertilization (at 60ºF), and incubation time of Southern DPS green sturgeon eggs is assumed to be similar (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). Because the incubation time for green sturgeon is so short, the effects analysis period for incubating eggs is considered to be the same as the spawning period, April through July, occasionally extending to October.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

During the April through July green sturgeon spawning period, CalSim 3 estimates of mean monthly flows at RBDD (RM 244) under the No Action Alternative and Alternative 4 range from about 5,000 cfs for April of critically dry water years to about 15,000 cfs in April of wet water years at RBDD and from about 5,000 cfs in April of critically dry water years and over 17,000 cfs in April of wet water years at Hamilton City (Table O-267 and Table O-269). Mean flows during most of this period at both locations are moderate (~8,000 cfs to ~13,000 cfs). At both locations, flows between Alternative 4 and the No Action Alternative remain similar in most months, but flows are moderately lower for Alternative 4 in May through July during critically dry water years (up to 8%) at RBDD and for July during critically dry water years at Hamilton City (up to 6%) (Table O-267 and Table O-269). During the August through October period, when green sturgeon spawning occurs in occasional years, the flows under both alternatives at both locations tend to be lower than those in April through July, but the mean flows would be close to or above 5,000 cfs for all water year types in all three months. A moderate reduction in mean flows from the No Action Alternative to Alternative 4 is predicted for August of critically dry water years at RBDD; however, the resulting Alternative 4 mean flows are greater than 7,000 cfs and would not be expected to have an adverse effect on spawning habitat. A moderate increase in flows under Alternative 4 is predicted in October of critically dry water years at both locations (up to 10%). Moderate increases in mean flow from No Action Alternative to Alternative 4 in October may or may not be substantial enough to have a positive effect on larval green sturgeon. September spawning occurs only sporadically, so any effect on the green sturgeon population would be minor (National Marine Fisheries Service 2018a). Flow levels at RBDD and Hamilton City are likely to be suitable for green sturgeon spawning and egg incubation, and no adverse effects are expected to result.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 49.3°F to 63.7°F range for spawning initiation during April through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 208 for Bend Bridge and Table 210 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 52.3°F to 60.8°F range supporting egg incubation during April

through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 216 for Bend Bridge and Table 218 for Hamilton City.

Results for the two analyses are summarized in Table O-67. Table O-67, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 49.3°F to 63.7°F spawning initiation range, there were zero and one month-water year type combinations (0% and 5.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-67). There were zero and two combinations (0% and 10.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 52.3°F to 60.8°F range for egg incubation, there were zero combinations (0%) with favorable results at Bend Bridge and Hamilton City. There were one and zero combinations (5.0% and 0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 4 on green sturgeon spawning and egg incubation.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on spawning habitats due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have beneficial and adverse water temperature-related impacts on spawning depending on location, month, and water year type.

Larval and Juvenile Rearing and Emigration

The green sturgeon spawning period is from April through July, so the larval period is considered to be April through September. The green sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch. The juveniles rear in the Sacramento River from about May through December. During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). Effects of flow and water temperature on green sturgeon larvae and juveniles may occur from April through December in the Sacramento River when analyzing the two life stages together.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

CalSim 3 modeling for the Sacramento River at RBDD indicates that mean monthly flows during the April through September period of larval rearing remain similar between Alternative 4 and the No Action Alternative. Reduced flows are predicted for May through August of critically dry years (up to 8%) (Table O-267). Reductions in flow from the No Action Alternative to Alternative 4 during critically dry years could potentially adversely affect green sturgeon larvae because, as discussed in Section O.1.3.2.5, *Green Sturgeon, Southern DPS*, there appears to be a positive relationship between annual outflow and abundance of white sturgeon larvae and juveniles, but the applicability of the relationship to green sturgeon is uncertain. Resulting

reduced flows remain above 7,000 cfs for all four months and would not be expected to have an adverse impact on larvae.

CalSim 3 modeling for the Sacramento River at Hamilton City indicates that mean monthly flows during the period of juvenile rearing and emigration, May through December, are higher in October of critically dry years (10%) and November of critically dry years (up to 13%) (Table O-269). Increases in flow could positively affect green sturgeon juveniles under Alternative 4 because, as discussed in Section O.1.3.2.5, *Green Sturgeon, Southern DPS*, there may be a positive relationship between annual outflow and abundance of juvenile green sturgeon.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 64.4°F upper threshold for larvae from May through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 220 for Bend Bridge and Table 222 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 66.2°F range of optimal juvenile bioenergetic performance during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 224 for Bend Bridge and Table 226 for Hamilton City.

Results for the two analyses are summarized in Table O-68. Table O-68 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 64.4°F upper water temperature limit for newly hatched larvae, there were one and two month-water year type combinations (5.0% and 10.0% of total combinations during the period, respectively) with favorable results at Bend Bridge and Hamilton City, respectively (Table O-68). There were zero and one combinations (0% and 5.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. For the 59°F to 66.2°F range of optimal juvenile bioenergetic performance, there were one and two combinations (6.7% and 13.3%, respectively) with favorable and unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be positive and negative water temperature-related effects of Alternative 4 on green sturgeon larval and juvenile rearing and emigration.

Summary

Alternative 4 relative to No Action Alternative is expected to have negligible impacts or possible beneficial impacts on rearing and emigration habitats. Alternative 4 relative to No Action Alternative is expected to have beneficial and adverse water temperature-related impacts on rearing and emigration depending on location, month, and water year type.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Sacramento River from the Delta as early as February to make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence. After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (Section O.1.3.2.5, *Green Sturgeon, Southern DPS*). With the extended adult

holding period, effects of flow and water temperature on adult upstream migration and holding may occur from February through December.

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

CalSim 3 Flows

Flows during the February through December period of green sturgeon immigration, spawning and holding are generally similar at RBDD and Hamilton City, except for the moderate increases and decreases discussed in Section O.7.14.1.1, *Spawning and Egg Incubation* and Section O.7.14.1.2, *Larval and Juvenile Rearing and Emigration* under Alternative 4 versus No Action Alternative (Table O-267 and Table O-269). Wilkins Slough shows increased flows during April of critically dry years (8%), October of critically dry years (up to 14%), and November of below normal and critically dry years (up to 17%) (Table O-268). A decrease in flows occurs at Wilkins Slough during July of critically dry years (5%). Flow differences in all three locations are not expected to substantially affect upstream passage of migrating green sturgeon, and the October and November flow increases under Alternative 4 at all three locations could result in improved habitat quality in holding pool habitats, positively affecting holding adults.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52°F to 69.4°F range for adult migration during April through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 204 for Bend Bridge and Table 206 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 52°F to 73.4°F range for adult holding year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 212 for Bend Bridge and Table 214 for Hamilton City.

Results for the two analyses are summarized in Table O-69. Table O-69, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 52°F to 69.4°F range for adult migration, there were no month-water year type combinations (0% of total combinations during the period, respectively) with favorable or unfavorable results at both Bend Bridge and Hamilton City, respectively (Table O-69). For the 59°F to 73.4°F range for adult holding, there was one month water-year type combination (1.7%) with favorable and unfavorable results at Bend Bridge and Hamilton City. There were six and zero combinations (10.0% and 0.0%, respectively) with unfavorable results at Bend Bridge and Hamilton City, respectively. These results suggest that there would be negative water temperature-related effects of Alternative 4 on green sturgeon adult upstream migration and holding.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts to possible beneficial impacts on upstream migration and holding habitats due to differences in flow. Alternative 4 is expected to result in water temperature-related adverse impacts on upstream migration and holding depending on location, month, and water year type.

O.7.11.2 San Joaquin River

Green sturgeon are also present in the San Joaquin River, but at considerably lower numbers than white sturgeon. Anglers have reported catching green sturgeon in the San Joaquin River and one adult green sturgeon was captured by Reclamation in April of 2020 (Root et al., 2020 [research note]). Although the reported presence of green sturgeon in the San Joaquin River coincides with the spawning migration period of green sturgeon within the Sacramento River, no evidence of spawning has been detected (Section O.1.8.2.3, *Green Sturgeon, Southern DPS*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Since green sturgeon spawning has not been confirmed in the San Joaquin River, life stage analyses were not performed. It is assumed that adult green sturgeon could be in the San Joaquin River during all months of the year.

During the evaluated months, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 4 range from about 681 cfs for July of critically dry water years with TUCP without VA to about 13,087 cfs for February of wet water years (Table O-281). Generally, flows remain similar between the No Action Alternative and Alternative 4. Increased flows are predicted under Alternative 4 for June through September of critically dry water years (up to 22%) (Table O-281). Increased flows under Alternative 4 during summer months may have a positive effect on adult green sturgeon.

Summary

Alternative 4 is expected to have possible beneficial impacts on adult green sturgeon relative to the No Action Alternative. Due to the lack of information about green sturgeon life stages in the San Joaquin River, a temperature analysis was not done for this species in this geography.

O.7.11.3 Bay-Delta

Larval and Juvenile Rearing and Emigration

After hatching, larvae and juveniles migrate downstream toward the Delta. Juveniles are believed to use the Delta for rearing for the first one to three years of their lives before moving out to the ocean and are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, especially within the central Delta and Suisun Bay/Marsh (Section O.1.9.1.5, *Green Sturgeon, Southern DPS*).

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

Differences in hydrology in the Delta under Alternative 4 compared with the No Action Alternative may have effects on flow routing into junctions and the hydrodynamic footprint of the export facilities. These possible differences were evaluated using several quantitative models which estimate the spatial extent of influence of exports under CVP and SWP diversions and estimate the proportion of flow entering a Delta junction: Zone of Influence and Flow into Junctions. In addition to these two analyses, a Delta Outflow vs. Sturgeon YCI regression analysis was done for the two sturgeon species to evaluate flow effects on sturgeon year class index.

Zone of Influence

Differences in hydrology under Alternative 4 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. With incremental decreases in OMR under Alternative 4 and the No Action Alternative, proportional overlap at these three locations decreases, with more subtle changes along the San Joaquin River at Jersey Point compared to Turner Cut and Old River at Middle River. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under Alternative 4 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2, *Zone of Influence*).

Flow into Junctions

Under Alternative 4 in all OMR bins except -3,500, predicted proportion of flow entering the CVP is less than the No Action Alternative. Changes in predicted proportion of flow entering the CVP in OMR bins -3,500, -5,000, and <-5,500 was less than ± 0.0372, indicating a negligible difference between Alternative 4 and the No Action Alternative. However, in OMR bin -2,000 the change in predicted proportion of flow into CVP was -0.0676 indicating that slightly less flow will be routed into CVP under Alternative 4 than when compared to the No Action Alternative.

Under Alternative 4 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering HOR is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.026, indicating a negligible difference between Alternative 4 and the No Action Alternative.

Delta Outflow vs. Sturgeon YCI

The Delta Outflow Year-Class Strength regression analysis found statistically significant positive correlations between white sturgeon year-class strength and Delta outflow for April-May and March-July. The analysis is used as a surrogate for green sturgeon. For the April-May Delta outflow, the average overall YCI values would be generally similar between Alternative 4 (10.7) and the No Action Alternative (11.2) (Table O-70). The same is true for the March-July Delta outflow, with the average overall YCI value for Alternative 4 being 16.4 compared to 16.7 for the No Action Alternative (Table O-71). Effects of Alternative 4 on green sturgeon relative to the No Action Alternative are expected to be limited given the limited differences in average Delta flow conditions between the two alternatives over all water year types during the specified months. For more detailed information see summaries presented in Attachment J.2*, Sturgeon Year Class Index and Delta Outflow*.

Summary

Alternative 4 relative to No Action is expected to influence flow into the HOR and CVP junctions due to differences in water management. Under Alternative 4, potentially less flow into CVP under OMR -2,000; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 4 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where

there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI). Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on green sturgeon year class strength using white sturgeon as a proxy for green sturgeon due to differences in flow.

Potential Changes to Entrainment of Southern DPS Green Sturgeon

Differences in exports under Alternative 4 compared with the No Action Alternative may have effects on green sturgeon entrainment at the Delta Fish Collection Facilities. These potential differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for green sturgeon include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of green sturgeon at SWP Banks Pumping Plant for the months January, and March of all water year types under Alternative 4 was less than or equal to predicted average monthly loss under the No Action Alternative for all water year types except for a 12% increase for wet water year types. For all other water year types Alternative 4 had a lower or equal predicted loss of green sturgeon at Banks compared to the No Action Alternative with up to a 3% reduction in loss for below normal water year types (Table O-72). Predicted average monthly loss of green sturgeon at the CVP Jones Pumping Plant for June through July under Alternative 4 was equal or lower compared to the No Action Alternative for all water year types, with up to a 11% reduction in predicted loss for dry water year types (Table O-73). It should be noted that loss of green sturgeon at both facilities is rare and infrequent, with such low values of predicted loss that the percent differences may not be representative. For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Summary

Differences in exports between Alternative 4 and the No Action Alternative are expected to have negligible impacts on the entrainment of juvenile green sturgeon at both facilities. Modeled results from the quantitative model show possible beneficial and adverse impacts, but since green sturgeon are salvaged so rarely, the numbers may not be representative.

Adult Upstream Migration and Holding

Adult green sturgeon move through the Delta from February through April to get to spawning locations in the upper Sacramento River. Following their initial spawning run upriver, adults split into two out migration groups, the “early” out migration group may migrate immediately back downstream through the Delta during May and June, or the “late” out migration group may hold for a few weeks to months in the upper river before moving back downstream during November through January (Section O.1.9.1.5, *Green Sturgeon, Southern DPS*).

Potential Changes to Southern DPS Green Sturgeon from Seasonal Operations

Delta Outflow vs. Sturgeon YCI

The Delta outflow vs Sturgeon YCI regression analysis results apply to all life stages of green sturgeon found in the Bay Delta. The regression analysis, used as a surrogate for green sturgeon, found statistically significant positive correlations between white sturgeon year-class strength and Delta outflow for April-May and March-July. Under Alternative 4, April-May Delta outflow average overall YCI values would be 4.5% lower (Table O-70) and the March-July Delta outflow values would be 1.8% lower (Table O-71) compared to the No Action Alternative. Refer to the analysis in Section O.7.11.3.1, *Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on green sturgeon year class strength due to differences in flow.

O.7.12 Delta Smelt

O.7.12.1 Bay-Delta

Adult Migration and Spawning

During winter, adult Delta smelt initiate upstream spawning migration in association with "first flush" flow events (Sommer et al. 2011). Others report this seasonal change as a multi-directional and more circumscribed dispersal movement to freshwater areas throughout the Delta region (Murphy and Hamilton 2013). By late winter-spring, after arriving in freshwater staging habitats, adult Delta smelt hold until spawning commences during favorable water temperatures (Bennett 2005; Grimaldo et al. 2009; Sommer et al. 2011; Damon et al. 2016). Delta smelt spawn over a wide area throughout much of the Delta, including the Sacramento River and San Joaquin River confluence, the upper Sacramento River, and Cache Slough as well as into Suisun Marsh and the Napa River as conditions allow (Brown et al. 2014; Murphy and Hamilton 2013). Spawning of Delta smelt has not been observed in the wild (Moyle et al. 2016).

Potential Changes to Delta Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 4 was similar to the No Action Alternative (Table O-270) during the adult Delta smelt migration and spawning period, only varying zero to two km from the No Action Alternative, likely having no to negligible effects on adult Delta smelt in the winter and spring.

USFWS Delta Smelt Life Cycle Model

The geometric mean of the expected rate of change in abundance across years (1995-2015), λ, for Alternative 4 was 0.88 (Attachment F.4., *Delta Smelt Life Cycle Model with Entrainment*). Like other Alternatives, the λ under Alternative 4 varied between water year types, from λ equal to 0.68 (-32% decline on average) for below normal, dry and critically dry water years, to λ equal to 1.18 (18% increase in λ on average) for wet and above normal years. Compared to the No Action Alternative, the results under Alternative 4 were similar in the direction and magnitude of the predicted trend, but Alternative 4 results were 3% to 8% lower in terms of population growth rates, depending on the water year type (Attachment F.4, *Delta Smelt Life Cycle Model with Entrainment*).

Revised Maunder and Deriso Life Cycle Model

Life cycle analysis with the MDR model for Alternative 4 showed negligible impact on Delta smelt population growth rates compared to the No Action Alternative. Differences in single-year λ values did not exceed +/-10% across all modeled years (1995-2015), and the geometric mean of λ was 0.75 for both Alternative 4 and the No Action Alternative (Attachment F.1, *Maunder and Deriso in R Model*).

Because the MDR is an integrated life cycle model, the effects of each alternative were evaluated quantitatively primarily based on year-to-year changes in the population growth rate metric. However, as a statistical model fitted to abundance data for multiple life-stages, it is possible to gain a qualitative understanding of the season-specific covariates with a statistically significant influence on each life-stage. Also, because the covariates are standardized prior to model fitting, their coefficients can be directly compared.

In the MDR model, survival from the sub-adult to adult stage can be influenced by winter covariates which are averaged across the December to February period. Model selection retained combined Old and Middle River flow (OMR) and mean Secchi depth at South Delta monitoring stations as significant covariates of sub-adult survival, with coefficients of 0.477 and 0.542, respectively. Although differences in hydrology between the Alternatives would be expected to influence turbidity, the relationship is complex and was not able to be addressed for this analysis. Within the MDR, impacts on sub-adult survival are therefore related only to differences in OMR between the Alternatives. Mean winter OMR differed negligibly from the No Action Alternative for Alternative 4 (-1.7% change), further indicating minimal potential for impacts on sub-adult Delta smelt survival via the modeled pathway.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the winter in the low salinity zone showed significant relationships for five zooplankton taxa; *Daphnia* adults, decapod larvae, *Eurytemora affinis* adults, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, for *Daphnia* adults the expected CPUE did not change for all water year types. Results for decapod larvae were negligible when rounded to the nearest whole integer (values were 0) across all WYT and scenarios. *E. affinis* adults had the largest expected CPUE increase of 1% during the wet and below normal water year type and did not change during the above normal, dry, and critically dry water year type. Other calanoid copepod

adults had the largest expected CPUE increase of 6% during the below normal water year type and did not change during the above normal, dry, and critically dry water year type. Other calanoid copepodites had the largest expected CPUE increase of 2% during below normal water year type and did not change during the above normal and critically dry water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflow under Alternative 4 during the winter were generally only slightly (<5%) different from the No Action Alternative for most water year types (Table O-272) resulting in only minor changes in zooplankton CPUE.

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, cladocerans (except *Daphnia*) expected CPUE did not change during the dry and critically dry water year type and the largest expected CPUE decrease of 4% during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 1% during the critically dry water year type and the smallest expected CPUE decrease of 2% during the above normal and below normal water year type. Harpacticoids had no expected change in CPUE during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. The CPUE of other calanoid copepod adults was not expected to change during the critically dry water year type and had the largest expected CPUE decrease of 3% during the above normal and below normal water year types. Other calanoid copepod copepodites had the largest expected CPUE increase of 1% during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 4 during the spring were generally only slightly (<5%) different from the No Action Alternative for most water year types, except outflow decreased in May for most water year types (Table O-272) resulting in minor decreases in zooplankton CPUE.

<u>Summary</u>

Alternative 4 relative to the No Action Alternative is expected to have adverse impacts on adult Delta smelt migration and spawning due to differences in flow. Compared to the No Action Alternative, CPUE of Delta smelt prey species was only slightly (<5%) different during both winter and spring. Results from the revised Maunder and Deriso life cycle model indicate that under Alternative 4 there would be minimal potential impacts on sub-adult to adult Delta smelt survival. Compared to the No Action Alternative, the USFWS lifecycle model results for Alternative 4 ranged 4 to 8% lower in terms of population growth rates depending on the water year type when compared to the No Action Alternative. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the winter and spring which is expected to have no impact on adult Delta smelt migration and spawning.

Potential Changes to Entrainment of Delta Smelt

Alternative 4 relative to the No Action Alternative may affect the entrainment of adult Delta Smelt due to differences in flow. Entrainment varies annually and depends on a combination of hydrology, turbidity, and export rates (see Smith et al. 2021). Historic salvage shows adult Delta smelt are entrained in the Delta Fish Collection Facilities, however in more recent years fewer fish have been entrained likely due to a combination of changes to operations and the continued decline of the Delta smelt population. While the USFWS life cycle model does incorporate entrainment, it was not used to evaluate entrainment of adult Delta smelt. Instead, OMR flows were used to evaluate changes between Alternative 4 and the No Action Alternative.

CalSim 3 OMR Values

In general, OMR combined flows were more negative under Alternative 4 when compared to the No Action Alternative from February to May, which would have adverse impacts on entrainment of adult Delta smelt but less negative in December, January and June which would have beneficial effects on entrainment of adult Delta smelt (Table O-273). The largest difference in OMR flows was in April during the above normal water year type (115% more negative) while largest increase in OMR flows was in December of wet years (24% more positive). In general, during the January to June period, OMR was more negative under Alternative 4 compared to No Action Alternative from February to May which would be detrimental for adult Delta smelt entrainment, while OMR was less negative in December, January and June which would be beneficial for adult Delta smelt entrainment.

Summary

Alternative 4 relative to the No Action Alternative is expected to have adverse and beneficial impacts on the entrainment of adult Delta smelt depending on the month due to differences in flow. OMR was more negative under Alternative 4 compared to No Action Alternative from February to May, which would be detrimental for adult Delta smelt entrainment, while OMR was less negative in December, January and June, which would be beneficial for adult Delta smelt entrainment.

Eggs and Larvae

Eggs hatch after an average of 10 days in the spring and planktonic larvae are transported (advected) from freshwater regions by the Sacramento River and tidal flows from March through May. The larval stage lasts for an average of 30 days. The nonpelagic habitats used by larval Delta smelt before they move into the pelagic areas are not known (Swanson et al. 1998; Sommer et al. 2011).

Potential Changes to Delta Smelt from Seasonal Operations

Differences in flows under Alternative 4 compared with the No Action Alternative may have effects on Delta smelt larvae including X2 position, population growth rate, and prey availability. These possible differences were evaluated using several quantitative models.

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 4 was similar to the No Action Alternative (Table O-270) during the larval Delta smelt period, only varying zero to two km from the No Action Alternative, likely having negligible effects on larval Delta smelt in the spring.

Revised Maunder and Deriso Life Cycle Model

Life cycle analysis with the Maunder and Deriso Model in R (MDR) did not identify any significant covariates of recruitment, and so did not evaluate effects on eggs or early larval stages.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for five zooplankton taxa. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, cladocerans (except *Daphnia*) expected CPUE did not change during the dry and critically dry water year type and the largest expected CPUE decrease of 4% during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 1% during the critically dry water year type and the smallest expected CPUE decrease of 2% during the above normal and below normal water year type. Harpacticoids had no expected change in CPUE during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. The CPUE of other calanoid copepod adults was not expected to change during the critically dry water year type and had the largest expected CPUE decrease of 3% during the above normal and below normal water year types. Other calanoid copepod copepodites had the largest expected CPUE increase of 1% during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 4 during the spring were generally only slightly (<5%) different from the No Action Alternative for most water year types, except outflow decreased in May for most water year types (Table O-272) resulting in minor decreases in zooplankton CPUE.

Summary

Alternative 4 relative to the No Action Alternative is largely expected to have minor adverse impacts on Delta smelt larvae due to differences in flow. Compared to the No Action Alternative, CPUE of Delta smelt prey species is expected to slightly decrease under Alternative 4. Results from the revised Maunder and Deriso life cycle model indicate that under Alternative 4 there would be a slight adverse impact (approximately 1%) on the survival of post-larval Delta smelt. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the spring which are expected to have negligible impacts on larval Delta smelt.

Potential Changes to Entrainment of Delta Smelt

Alternative 4 compared with the No Action Alternative may affect the entrainment of Delta smelt larvae due to differences in flow. This possible difference was evaluated using a quantitative model.

Particle Tracking Model (PTM)

Inflow Bins.

Depending on inflow conditions, an average of 0 to 12% of particles injected within the Sacramento River region would be entrained at export facilities under Alternative 4, compared to 0 to 14% under the No Action Alternative. The average percentage of particles entrained at exports ranged from 12% lower than for the No Action Alternative under "medlo" inflow conditions (14% under the No Action Alternative *vs* 12% under Alternative 4) to 70% higher than for the No Action Alternative under "medhi" inflow conditions (but note that the absolute entrainment remained low at around 2% and close to 1% entrainment under the No Action Alternative).

Depending on inflow conditions, an average of 53 to 91% of particles injected within the San Joaquin River region would be entrained at export facilities under Alternative 4, compared to 45 to 87% under the No Action Alternative. Differences in potential entrainment between Alternative 4 and the No Action Alternative ranged from -1% under "medlo" inflow conditions to +27% under "medhi" inflow conditions. Although not discussed here in detail, a similar pattern was observed for other injection regions with moderate potential for particles entrainment. Alternative 4 would lead to minor reductions in the average percentage of particles entrained compared to the No Action Alternative under "medlo" inflow conditions (-7% for the Central Delta injection region or -6% for the Mokelumne River injection region) and to the largest increases in potential entrainment under "medhi" inflow conditions compared to the No Action Alternative (+71% for the Central Delta injection region or +66% for the Mokelumne River injection region).

Depending on inflow conditions, an average of 0 to 4% of particles injected within the Yolo Bypass region would be entrained at export facilities under Alternative 4, compared to 0 to 5% under the No Action Alternative. Differences in potential entrainment between Alternative 4 and the No Action Alternative ranged from -32% under "hilo" inflow conditions to +74% under "medhi" inflow conditions (note, however, that average entrainment for this injection region remained low at around between 0 and 4%.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), there was a difference between the average percentage of particles entrained under Alternative 4 and under the No Action Alternative (-1 to +27%).

OMR bins.

Depending on OMR flow conditions, an average of 57 to 80% of particles injected within the San Joaquin River region would be entrained at export facilities under Alternative 4, compared to 57 to 87% under the No Action Alternative. Potential entrainment ranged from 8% lower under Alternative 4 than under the No Action alternative for the -5000 OMR bin (80% *vs* 87%) to 9% higher for the -3500 bin (74 *vs* 68%). Although not discussed here in detail, a similar pattern was observed for other injection regions with moderate potential for particles entrainment at export facilities (Mokelumne River, Sacramento River, Central Delta): Alternative 4 would generally lead to substantial reductions in the average percentage of particles entrained compared to the No Action Alternative for the most negative OMR index (-5000: -35 to -58%), minor decreases to moderate increases under the less negative OMR index (-2000: -4 to +25%), and increases for intermediate OMR index (-3500: +33 to +49%).

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of OMR flow conditions, there was generally little difference between the average percentage of particles entrained under Alternative 4 and under the No Action Alternative (-2 to +1%).

Summary

Alternative 4 relative to the No Action Alternative for injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta) is expected to have a negligible to adverse impact on the entrainment of larval Delta Smelt. Alternative 4 relative to the No Action Alternative is expected for injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta) to have negligible impacts on the entrainment of larval Delta smelt, with some increased and reduced entrainment depending on OMR grouping due to differences in flows.

Juveniles

During and after larval rearing in freshwater, many young Delta smelt move with river and tidal currents during the early summer to remain in favorable rearing habitats, often moving into low salinity ($\leq$ 6 psu) areas to avoid seasonally warm and highly transparent waters that typify many areas in the central Delta (Nobriga et al. 2008). Juvenile Delta smelt rearing habitat is correlated with salinity, particularly the position of the LSZ, and other habitat attributes like turbidity and temperature. Delta smelt also rear in upstream areas such as the Cache Slough complex and Sacramento Deep Water Ship Channel, depending on habitat conditions (Sommer and Mejia 2013). Studies indicate that in fall, prior to spawning, juvenile and sub-adult Delta smelt tend to remain in the LSZ (Sommer et al. 2011), though they can be found in the lower San Joaquin River, Suisun and San Pablo bays, the Sacramento River and San Joaquin River confluence, Cache Slough, and the lower Sacramento River (Murphy and Hamilton 2013).

Potential Changes to Delta Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 4 was similar the No Action Alternative (Table O-270) and varied from zero to two km during the juvenile Delta smelt rearing period for below normal, dry and critically dry water year types, likely having no effects on juvenile Delta smelt in the summer and fall. However, the position of X2 was two to five km further landward during wet and above normal water year types in the fall, likely having an adverse effect on juvenile Delta smelt during the fall.

Habitat Suitability Index

Juvenile Delta smelt summer and fall habitat was estimated for different water year types (wet, above normal, below normal, dry, and critical) using the Bever et al. (2016) habitat suitability index (Bever HSI) and the Bever HSI with a water temperature threshold of 22° Celsius (22C HSI), where the Bever HSI value is multiplied by zero when water temperature is greater than 22° C and by one when water temperature is less than or equal to 22° C. The temperature threshold of 22ºC was used based on sub-lethal physiological and behavioral effects observed in multiple studies (Davis et al. 2022; Hammock et al. 2022; Komoroske et al. 2021; Lewis et al. 2021; Davis et al. 2019; Komoroske et al. 2015). Under Alternative 4, mean Bever HSI for

subregions targeted by the summer fall habitat action (Yolo Bypass, which includes Cache Slough and Sacramento Deepwater Shipping Channel; Lower Sacramento River; Confluence; Suisun Marsh; northwest Suisun Bay) was 3% to 6% lower than under the No Action Alternative, depending on water year type. Under Alternative 4, the mean 22C HSI for the summer fall habitat action subregions was 8% lower to less than 1% higher than under the No Action Alternative, depending on water year type. The largest differences under Alternative 4 are predicted during the dry water year for mean Bever HSI (6% lower) and during the critical water year for mean 22C HSI (8% lower). The smallest differences are predicted during the above normal water year for mean Bever HSI (1% lower) and for mean 22C HSI (< 1% lower).

The results of the HSI analyses suggest that Alternative 4 may result in minor increases (< 1%) and decreases (1-8%) in suitable habitat depending on water year type and the application of a temperature threshold in comparison to the No Action Alternative and would likely have negligible to minor adverse impacts on juvenile Delta smelt summer and fall habitat.

Revised Maunder and Deriso Life Cycle Model

Summer outflow, the only variable within the Maunder and Deriso Model in R (MDR) with influence on the larval life-stage, was approximately 1% lower under Alternative 4 than under the No Action Alternative, and so minimal impact on post-larval survival would be expected (Attachment F.1, *Maunder and Deriso in R Model*).

The preferred set of covariates identified through extensive model selection did not include any parameters that differed between alternatives (Attachment F.1, Maunder and Deriso in R Model). Mean Delta water temperature and Secchi depth were the selected parameters for the fall period, which correspond to juvenile survival in the MDR model. Although hydrological differences between the alternatives would potentially impact these variables, the relationships between flow, temperature and turbidity are complex, and were not able to be modeled for this exercise. As such, juvenile Delta smelt survival under Alternative 4 was the same as under the No Action Alternative.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the fall showed significant relationships for two taxa; *E. affinis* adults and mysids. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, for *E. affinis* there was no expected change in CPUE across all water year types.. However, the expected CPUE for *E. affinis* during the fall was very low (one to three individuals per cubic meter) and unlikely to impact Delta smelt juveniles. Mysids had the largest expected CPUE increase of 8% during the above normal water year type and was not expected to change for all other water year types. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 4 during the fall were generally only minorly (<5%) different from the No Action Alternative for most water year types (Table O-272) resulting in only minor changes in zooplankton CPUE.

Summary

Alternative 4 relative to the No Action Alternative is expected to have minor impacts on juvenile Delta smelt due to differences in flow. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the summer and fall, which is expected to have negligible impacts on juvenile Delta smelt. The results of the HSI analyses suggest that Alternative 4 depending on water year type and the application of a temperature threshold in comparison to the No Action Alternative would likely have minor adverse impacts on juvenile Delta smelt summer and fall habitat. Results from the revised Maunder and Deriso life cycle model did not include any parameters that differed between alternatives and therefore survival under Alternative 4 was the same as under the No Action Alternative. Compared to the No Action Alternative, CPUE of Delta smelt prey species was not related to outflow in the summer and the CPUE is expected to slightly change compared to the No Action Alternative during the fall.

Potential Changes to Entrainment of Delta Smelt

Alternative 4 relative to the No Action Alternative may affect the entrainment of juvenile Delta smelt due to differences in flow. Entrainment varies annually and depends on a combination of hydrology, turbidity, and export rates (see Smith et al. 2021). Historic salvage shows juvenile Delta smelt are entrained in the Delta Fish Collection Facilities, however in more recent years fewer fish have been entrained likely due to a combination of changes to operations and the continued decline of the Delta smelt population. While the USFWS life cycle model does incorporate entrainment, it was not used to evaluate entrainment of adult Delta smelt. Instead, OMR flows were used to evaluate changes between Alternative 4 and the No Action Alternative.

CalSim 3 OMR Values

OMR combined flows ranged from no differences to less negative under Alternative 4 when compared to the No Action Alternative from June to November, which would have negligible to positive effects on entrainment of juvenile Delta smelt (Table O-273). The largest difference in OMR flows under Alternative 4 compared with the No Action Alternative were in June during the dry water year type (10% less negative), while OMR flows were more negative in September during the above normal water year type (21% more negative) compared to the No Action Alternative. In general, during the June to November period, OMR was less negative under Alternative 4 compared to No Action Alternative in June and similar to the No Action Alternative from July to November, which would have negligible effects.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible to beneficial impacts on the entrainment of juvenile Delta smelt due to differences in flow. OMR flow for Alternative 4 was less negative in June, compared to the No Action Alternative, which would have beneficial impacts for entrainment of juvenile Delta smelt. OMR flow for Alternative 4 was similar to the No Action Alternative from July to November, which would have negligible impacts.

O.7.13 Longfin Smelt

O.7.13.1 Bay Delta

Adult Migration and Spawning

Longfin smelt are anadromous and spawn in fresh or low-salinity water in the Bay-Delta (Grimaldo et al. 2017), generally at 2 years of age (Moyle 2002). A portion of the population migrate from the ocean into the San Francisco Estuary and move upstream to spawn during late fall through winter, with most spawning occurring from November through April (California Department of Fish and Wildlife 2009a). Spawning locations have been estimated using field observations of gravid females and yolk-sac larvae (Grimaldo et al. 2017, Lewis et al. 2019) and through particle-tracking modeling (Gross et al. 2022) to suggest spawning extends farther seaward than previously thought (Moyle 2002). Based on these studies, longfin smelt appear to spawn in the low-salinity zone where brackish and freshwaters meet (Grimaldo et al. 2017), and in tidal wetlands of south San Francisco Bay and San Pablo Bay when hydrological conditions favor spawning in more seaward regions (Lewis et al. 2020, Grimaldo et al. 2020). These regions include marshes of the Petaluma watershed, Napa-Sonoma watershed, Sacramento-San Joaquin watershed, and Coyote Creek watershed (Lewis et al. 2020, Hobbs et al. 2015).

Potential Changes to Longfin Smelt from Seasonal Operations

<u>CalSim 3 X2 Modeled X2 Position</u>

The position of X2 under Alternative 4 was similar to the No Action Alternative (Table O-270) during the adult longfin smelt migration and spawning period, only varying zero to two km from the No Action Alternative, likely having negligible impacts on adult longfin smelt in the fall, winter and spring.

<u>Zooplankton CPUE-Outflow Analysis</u>

Analysis of CPUE with outflow during the fall showed significant relationships for two taxa; *E. affinis* adults and mysids. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, for *E. affinis* there was no expected change in CPUE across all water year types. However, the expected CPUE for *E. affinis* during the fall was very low (one to three individuals per cubic meter) and unlikely to impact longfin smelt. Mysids had the largest expected CPUE increase of 8% during the above normal water year type and was not expected to change for all other water year types. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 4 during the fall were generally only minorly (<5%) different from the No Action Alternative for most water year types (Table O-272) resulting in only minor changes in zooplankton CPUE.

Analysis of CPUE with outflow during the winter in the low salinity zone showed significant relationships for five zooplankton taxa; *Daphnia* adults, decapod larvae, *Eurytemora affinis* adults, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, for *Daphnia* adults the expected CPUE did not change for all water year types. Results for decapod larvae were negligible when rounded to the nearest

whole integer (values were 0) across all WYT and scenarios. *E. affinis* adults had the largest expected CPUE increase of 1% during the wet and below normal water year type and did not change during the above normal, dry, and critically dry water year type. Other calanoid copepod adults had the largest expected CPUE increase of 6% during the below normal water year type and did not change during the above normal, dry, and critically dry water year type. Other calanoid copepodites had the largest expected CPUE increase of 2% during below normal water year type and did not change during the above normal and critically dry water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflow under Alternative 4 during the winter were generally only slightly (<5%) different from the No Action Alternative for most water year types (Table O-272) resulting in only minor changes in zooplankton CPUE.

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, cladocerans (except *Daphnia*) expected CPUE did not change during the dry and critically dry water year type and the largest expected CPUE decrease of 4% during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 1% during the critically dry water year type and the smallest expected CPUE decrease of 2% during the above normal and below normal water year type. Harpacticoids had no expected change in CPUE during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. The CPUE of other calanoid copepod adults was not expected to change during the critically dry water year type and had the largest expected CPUE decrease of 3% during the above normal and below normal water year types. Other calanoid copepod copepodites had the largest expected CPUE increase of 1% during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 4 during the spring were generally only slightly (<5%) different from the No Action Alternative for most water year types, except outflow decreased in May for most water year types (Table O-272) resulting in minor decreases in zooplankton CPUE.

<u>Summary</u>

Alternative 4 relative to the No Action Alternative is expected to have minor impacts on adult longfin smelt migration and spawning due to differences in flow. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to minorly increase and decrease under Alternative 4 during the fall, winter, and spring, depending on water year type. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative which are expected to have a negligible impact on adult longfin smelt migration and spawning in the fall, winter, and spring.

Potential Changes to Entrainment of Longfin Smelt

Differences in flow between Alternative 4 and the No Action Alternative may affect the entrainment of adult longfin smelt. Entrainment varies annually and depends on a combination of hydrology and export rates.

CalSim 3 Modeled X2 Position

The position of X2 under Alternative 4 was similar to the No Action Alternative (Table O-270) during the adult longfin smelt migration and spawning period, only varying zero to two km from the No Action Alternative.

CalSim 3 Modeled OMR Flow

Total exports during the adult longfin smelt migration and spawning period under Alternative 4 were lower during December and higher in February, and April across all water year types and March for the wet and above normal water year type when compared to the No Action Alternative (Table O-273). OMR flow values were less negative in December and more negative in February and April across all water year types and March for the wet and above normal water year type when compared to the No Action Alternative. OMR values were still under the -5000 cfs threshold value. Compared to the No Action Alternative, under Alternative 4, there are likely minor beneficial impacts during the early winter and minor adverse impacts during late winter and spring.

Summary

Alternative 4 relative to the No Action Alternative is expected to have adverse to beneficial impacts on entrainment of adult longfin smelt during migration and spawning due to differences in flow. Compared to the No Action Alternative, the position of X2 only varied 0-1 km under Alternative 4, likely having a negligible impact on adult longfin smelt. Compared to the No Action Alternative, exports decreased in the December and increased in the February and April, while OMR values were less negative in December and more negative in February and April likely resulting in minor adverse and minor beneficial impacts depending on the month.

Eggs and Larvae

In the San Francisco Estuary, most longfin smelt larvae hatch between December and May, and rarely outside of this range (Baxter 1999). Longfin smelt larvae are most abundant in the water column usually from January through April (Bureau of Reclamation 2008). Larval longfin smelt rear in low salinity to brackish water (2–12 ppt; Grimaldo et al. 2017) and in tidal wetlands of San Pablo Bay (Sonoma Creek, Napa River, and Petaluma River) and south San Francisco Bay (Alviso Marsh Complex and salt pond restoration areas) (Hobbs et al. 2015, Lewis et al. 2020). The spatial distribution of these larvae reflects the year-to-year variation in freshwater outflow which affects the geographic location of the low-salinity zone during the winter and spring (Feyrer et al. 2004, Grimaldo et al. 2020). During high outflow years, the low salinity zone can extend into San Pablo Bay. Within the low-salinity zone and adjacent waters, larvae have been commonly collected in both littoral (nearshore) and pelagic (offshore) habitats.

Potential Changes to Longfin Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 4 was similar to the No Action Alternative (Table O-270) during the larval longfin smelt period, only varying zero to two km from the No Action Alternative, likely having negligible impacts on larval longfin smelt in the spring.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, cladocerans (except *Daphnia*) expected CPUE did not change during the dry and critically dry water year type and the largest expected CPUE decrease of 4% during the above normal water year type. *E. affinis* adults had the largest expected CPUE increase of 1% during the critically dry water year type and the smallest expected CPUE decrease of 2% during the above normal and below normal water year type. Harpacticoids had no expected change in CPUE during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. The CPUE of other calanoid copepod adults was not expected to change during the critically dry water year type and had the largest expected CPUE decrease of 3% during the above normal and below normal water year types. Other calanoid copepod copepodites had the largest expected CPUE increase of 1% during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 4 during the spring were generally only slightly (<5%) different from the No Action Alternative for most water year types, except outflow decreased in May for most water year types (Table O-272) resulting in minor decreases in zooplankton CPUE.

Summary

Alternative 4 is expected to have minor impacts on longfin smelt eggs and larvae due to differences in flow. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to minorly increase and decrease under Alternative 4 during the spring, depending water year type. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the spring which are expected to have negligible impacts on larval longfin smelt.

Potential Changes to Entrainment of Longfin Smelt

Alternative may affect the entrainment of larval longfin smelt. This possible difference was evaluated using a quantitative model.

Particle Tracking Model (PTM)

Inflow Bins.

Depending on inflow conditions, an average of 1 to 19% (SO) or 1 to 16% (NB) of particles injected within the Sacramento River region would be entrained at export facilities under Alternative 4, compared to 1 to 16% (SO and NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 15% lower (SO) or 16% lower (NB) under “medlo” conditions to 19% higher (SO) or 22% higher (NB) under “lohi” conditions for Alternative 4 compared to the No Action Alternative.

Depending on inflow conditions, an average of 0 to 4% (SO and NB) of particles injected within the Western Delta region would be entrained at export facilities under Alternative 4, compared to 0 to 4% (SO) and 0 to 3% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 36% lower (SO) or 44% lower (NB) than the No Action Alternative for Alternative 4 under "medmed" conditions to 82% higher (SO) or 155% higher (NB) under "hihi" conditions. Note however that under these conditions the overall percentage of particles entrained would remain extremely low (close to 0 for both Alternative 4 and the No Action Alternative).

Depending on inflow conditions, an average of 0 to 9% (SO) or 0 to 7% (NB) of particles injected within the Yolo Bypass region would be entrained at export facilities under Alternative 4, compared to 0 to 7% (SO) and 0 to 5% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 17% lower (SO) or 20% lower (NB) under "medlo" conditions to 31% higher under "hihi" conditions (SO) or 37% higher under "lohi" conditions (NB) for Alternative 4 compared to the No Action Alternative. However, note that the overall percentage of particles entrained would remain extremely low under such conditions (close to 0 for both Alternative 4 and the No Action Alternative).

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), there was a negligible difference between the average percentage of particles entrained under Alternative 4 and under the No Action Alternative (-2 to +2% NB and SO).

OMR bins.

Depending on OMR flow conditions, an average of 26 to 66% (SO) or 23 to 64% (NB) of particles injected within the Central Delta region would be entrained at export facilities under Alternative 4, compared to 24 to 81% (SO) and 22 to 79% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 18% lower (SO) or 19% lower (NB) under Alternative 4 than under the No Action Alternative for the -5500 OMR bin to 17% higher (both SO and NB) for the -3500 OMR bin.

Depending on OMR flow conditions, an average of 25 to 69% (SO) or 22 to 66% (NB) of particles injected within the Mokelumne River region would be entrained at export facilities under Alternative 4, compared to 23 to 78% (SO) and 21 to 75% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 12% lower (SO) and 13% lower (NB) under Alternative 4 than under the No Action Alternative for the -5500 OMR bin to 17% higher (both SO and NB) for the -3500 OMR bin.

Depending on OMR flow conditions, an average of 2 to 10% (SO) or 1 to 8% (NB) of particles injected within the Yolo Bypass region would be entrained at export facilities under Alternative 4, compared to 2 to 16% (SO) or 1 to 13% (NB) under the No Action Alternative. The average percentage of particles entrained at exports ranged from 38% lower (SO) or 39% lower (NB) under Alternative 4 than under the No Action Alternative for the -5500 OMR bin to 19% higher (SO) and 22% higher (NB) for the -3500 OMR bin.

For injections regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), regardless of OMR flow conditions, there was generally little difference between the average percentage of particles entrained under Alternative 4 and under the No Action Alternative (-2 to +2% NB and SO).

Summary

The percentage of particles entrained at exports were generally similar between surface-oriented particles representative of yolk-sac larval longfin smelt and neutrally buoyant particles representative of >10mm larval longfin smelt. For injection regions with high potential for entrainment at export facilities (Old and Middle River, Southern Delta), Alternative 4 compared to the No Action Alternative is expected to have a negligible impact on the entrainment of larval longfin smelt, for all inflow groupings and OMR groupings.

Juveniles

Juveniles have been detected throughout the San Francisco Estuary and rarely in some Delta tributaries (Merz et al. 2013). Juveniles gradually move seaward as they grow and as water temperatures increase in the late spring and early summer (Rosenfield and Baxter 2007; Tobias and Randall 2021). Seasonal patterns in abundance and occurrence in the nearshore ocean suggest that the population is at least partially anadromous (Rosenfield and Baxter 2007; Garwood 2017). The detection of longfin smelt within the estuary throughout the year and geochemical analysis of otoliths suggests longfin smelt in the San Francisco Estuary utilize several life history strategies (Lewis et al. 2019).

Potential Changes to Longfin Smelt from Seasonal Operations

CalSim 3 X2 Modeled X2 Position

The position of X2 under Alternative 4 was similar to the No Action Alternative (Table O-270) during the juvenile longfin smelt period, only varying 0-2 km from the No Action Alternative, likely having negligible impacts on juvenile longfin smelt in the spring and summer.

Longfin Smelt Abundance-Outflow Analysis

Juvenile Longfin Smelt abundance as represented by the Fall Midwater Trawl index of abundance is predicted to be equal to or less than 5% lower under Alternative 4 than the No Action Alternative, regardless of water year type (Attachment J.1, *Longfin Smelt Outflow*, Table 3). The difference in predicted abundance under Alternative 4 ranges from 0% (no difference) during wet and below normal years to 1% lower during above normal, dry, and critical water years compared to predicted abundance under the No Action Alternative.

Zooplankton CPUE-Outflow Analysis

Analysis of CPUE with outflow during the spring in the low salinity zone showed significant relationships for five zooplankton taxa; cladocerans (except *Daphnia*), *Eurytemora affinis* adults, harpacticoids, other calanoid adults, and other calanoid copepodites. In general, CPUE tended to decrease as the water year type became drier and outflow decreased. Under Alternative 4, when compared to the No Action Alternative, cladocerans (except *Daphnia*) expected CPUE did not change during the dry and critically dry water year type and the largest expected CPUE decrease of 4% during the above normal water year type. *E. affinis* adults had the largest expected CPUE

increase of 1% during the critically dry water year type and the smallest expected CPUE decrease of 2% during the above normal and below normal water year type. Harpacticoids had no expected change in CPUE during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. The CPUE of other calanoid copepod adults was not expected to change during the critically dry water year type and had the largest expected CPUE decrease of 3% during the above normal and below normal water year types. Other calanoid copepod copepodites had the largest expected CPUE increase of 1% during the critically dry water year type and the largest expected CPUE decrease of 2% during the above normal and below normal water year type. (Attachment J.3, *Zooplankton-Delta Outflow Analysis*). The CalSim 3 simulated average Delta outflows under Alternative 4 during the spring were generally only slightly (<5%) different from the No Action Alternative for most water year types, except outflow decreased in May for most water year types (Table O-272) resulting in minor decreases in zooplankton CPUE.

Summary

Alternative 4 is expected to have negligible to minor adverse impact on juvenile longfin smelt, relative to the No Action Alternative. Juvenile longfin smelt abundance as represented by the Fall Midwater Trawl index of abundance is predicted to be no different to minorly lower under Alternative 4 than it is for the No Action Alternative. Compared to the No Action Alternative, CPUE of longfin smelt prey species is expected to minorly decrease under Alternative 4 during the spring. CalSim 3 results indicate that the position of X2 did not greatly differ from the No Action Alternative during the spring and summer which is expected to have a negligible impact on juvenile longfin smelt.

Potential Changes to Entrainment of Longfin Smelt

Longfin Smelt Outflow Entrainment

Changes in OMR flows under Alternative 4 compared with the No Action Alternative may have an impact on LFS salvage. Compared to the No Action Alternative, predicted salvage increases ranged from 23% during the critically dry water year type to 185% during the above normal water year type. Alternative 4 had the more negative mean April-May OMR values compared to the No Action Alternative across all water year types and therefore higher predicted salvage. Overall modeling for Alternative 4 suggests that longfin smelt salvage would increase substantially when compared to the No Action Alternative. (Attachment I.4, *Longfin Smelt Salvage-OMR Relationship*).

Summary

Alternative 4 is expected to have an adverse impact on the entrainment of longfin smelt due to differences in flow.

O.7.14 Fall-run and Late Fall-run Chinook Salmon ESU

O.7.14.1 Sacramento River

Spawning and Egg/Alevin Incubation

Fall-run Chinook salmon typically spawn in the Sacramento River, primarily between Keswick Dam and RBDD from October through December, with incubation occurring from October through April. Peak spawning time for late fall-run Chinook salmon generally is from January through April (National Marine Fisheries Service 2009a), with incubation typically lasting for approximately 2 to 4 months between April and June (Moyle 2002). See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 4, differences in mean spawning WUA are generally lower than the No Action Alternative across the water year types, except in critically dry water years (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 4 and the No Action Alternative is a 1.1% increase in critically dry water years. The largest reduction in estimated spawning habitat is a -1.4% decrease in below normal water year types.

The monthly median value of spawning WUA under Alternative 4 is similar to the No Action Alternative throughout all of the spawning months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are relatively similar in September and October, and slightly lower in November and December. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are consistently highest in December when compared to other spawning months (Table O-266). This results in lower spawning WUA results because the fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of the spawning habitat analysis based on CalSim 3 simulated flows suggest that Alternative 4 may have a minor (less than 2%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. Out of the four months of potential fall-run Chinook salmon spawning, September and October have the highest estimated spawning WUA across all alternatives.

Fall-run Chinook Salmon: Redd Dewatering Analysis

Fall-run Chinook salmon mean redd dewatering potential under Alternative 4 increases from drier to wetter water year types (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). Most egg incubation of fall-run Chinook salmon occurs during fall and winter, when periodic storms and high runoff in wetter years result in increased flow fluctuations, increasing risk of redd dewatering. In drier winters, flow fluctuations are reduced and fewer redds are dewatered. Most differences in mean fall-run Chinook salmon redd dewatering potential between Alternative 4 and the No Action Alternative are small, except for a reduction of 20.7% in redd dewatering for

above normal water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). Other differences range from 6.77.3% lower in wet water years to 6.8% higher in critically dry water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). The apparent magnitude of the relative differences for fall-run are misleading because of the generally small levels of redd dewatering potential. For instance, for above normal water years the reduction is from 14.5% to 11.5%, an absolute difference of 3.0%, and for critically dry years the increase is from 6.3% to 6.7%, an absolute difference of 0.4%.

Overall, the results indicate that fall-run Chinook salmon redd dewatering potential under Alternative 4 is similar to that under the No Action Alternative.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 235 for Keswick Dam and Table 236 for RBDD. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 238 for Keswick Dam and Table 239 for RBDD. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during December through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 241 for Keswick Dam and Table 242 for RBDD.

Results for the three analyses are summarized in Table O-74. Table O-74, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 42.1°F to 55°F spawning initiation range analysis, there were one and zero month-water year type combinations (5.0% and 0% of total combinations during the period) with favorable results at both Keswick Dam and RBDD (Table O-74). There was zero and one combinations (0.0% and 5.0%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 59.9°F pathogen virulence threshold, there also was one combination (5.0%) with favorable results at both Keswick Dam and RBDD and no combinations with unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were no combinations (0%) with favorable or unfavorable results at both locations. These results suggest that there would be negligible positive and negative water temperature-related effects of Alternative 4 on fall-run Chinook salmon spawning and egg/alevin in the Sacramento River.

Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on redd dewatering from sudden drops in flow. However, redd surveys occur during the pulse flow period and redd dewatering has not been observed.

Fall-run Chinook Salmon: Summary

The change in seasonal operations in the Sacramento River between Alternative 4 and the No Action Alternative are expected to have minor impacts on fall-run Chinook salmon spawning habitat and incubation. Under Alternative 4, changes in flows may have a minor increase and decreases in spawning habitat area in all water year types. The potential for redd dewatering would be similar to the No Action Alternative. There may be redd dewatering following spring pulse flow events, though this has not been observed during redd surveys. Under Alternative 4, there would be favorable and unfavorable water temperature conditions for fall-run Chinook salmon spawning and egg/alevin incubation in the Sacramento River.

Late Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 4, differences in mean spawning WUA are generally lower than the No Action Alternative across the water year types, except in critically dry water years (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat between Alternative 4 and the No Action Alternative is a 1.1% increase in critically dry water years. The largest reduction in estimated spawning habitat is a 1.4% decrease in below normal water year types.

The monthly median value of spawning WUA under Alternative 4 is similar to the No Action Alternative throughout all of the spawning months (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). Spawning WUA median values for all the modeled alternatives are also relatively similar across all three spawning months. The CalSim 3 simulated average flows in the Sacramento River below Keswick Dam are highest in February but all three months are above 8,000 cfs (Table O-266). This results in spawning WUA results that are approximately the same across all three months because the late fall-run Chinook salmon spawning WUA curves (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*), peak at relatively low flows (approximately 3,000 to 6,000 cfs).

The results of the spawning habitat analysis based on CalSim 3 simulated flows suggest that Alternative 4 may have a negligible (less than 1.5%) increase and/or decrease in estimated spawning habitat across all water year types when compared to the No Action Alternative in the mainstem upper Sacramento River. The three months of potential late fall-run Chinook salmon spawning have similar estimated spawning WUA across all alternatives.

Late Fall-run Chinook Salmon: Redd Dewatering Analysis

The results for Alternative 4 show substantial increases in percentage of late fall-run Chinook salmon redds dewatered with water year type, varying from high redd dewatering in wet water years to low redd dewatering in critically dry water years (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). This pattern of variation reflects flow conditions for the winter and spring months when late fall-run Chinook salmon spawning and incubation occurs (Table O-266). During wet winters and springs, periodic storms and high runoff increase flow and flow variability, which tends to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. Mean redd dewatering potential is similar between Alternative 4 and the No Action Alternative in all water year types except for critically dry water years, for which redd dewatering is 15.6% higher under Alternative 4 (Attachment L.4, *Sacramento River Redd Dewatering Analysis*). Other differences range from 3.1% lower for

critically dry water years to 4.5% higher for wet years. Note that the 15.5% increase for critically dry years represents an absolute difference in redd dewatering of 0.4%.

Overall, the results indicate that late fall-run Chinook salmon redd dewatering potential is similar between Alternative 4 and the No Action Alternative, except for increased redd dewatering in critically dry water years.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 267 for Keswick Dam and Table 268 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 270 for Keswick Dam and Table 271 for below Clear Creek. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 273 for Keswick Dam and Table 274 for below Clear Creek.

Results for the three analyses are summarized in Table O-75. Table O-75, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0%) with favorable and unfavorable results at Keswick Dam and Clear Creek, respectively (Table O-75). For the 59.9°F pathogen virulence threshold, there were no combinations (0%) with favorable or unfavorable results at both locations. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were two and four combinations (10.0% and 20.0%, respectively) with favorable results at Keswick Dam and Clear Creek, respectively. There were zero combinations (0%) with unfavorable results at both locations. These results suggest that there would generally be negligible effects of Alternative 4 on late fall-run Chinook salmon spawning and egg incubation, with a beneficial effect for egg incubation and fry emergence below Clear Creek.

Late Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on spawning behavior and redd dewatering from sudden drops in flow. However, redd surveys occur during the pulse flow period and redd dewatering has not been observed.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in the Sacramento River between Alternative 4 and the No Action Alternative are expected to have minor impacts on late fall-run Chinook salmon spawning habitat and incubation. Under Alternative 4, flows would be similar to the No Action Alternative in all water year types and so would have similar effects to spawning habitat and redd dewatering. There may be changes to spawning behavior and redd dewatering with spring pulse

flow events, but redd dewatering has not been observed during the pulse flow period. Under Alternative 4, conditions caused by water temperatures for spawning initiation and pathogen virulence would be similar to the No Action Alternative. Egg incubation and emergence would have more favorable conditions when compared with the No Action Alternative.

Juvenile Rearing and Emigration

The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, mostly between January through June. Late fall-run Chinook salmon juveniles typically enter the ocean after 7 to 13 months of rearing in freshwater, generally between October and February. See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under Alternative 4, mean fry rearing WUA decreases in below normal, dry, and critically dry water year types and increases in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 0.3% increase in wet water year types. The largest reduction in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 0.9% decrease in dry water year types.

The monthly median value of fry rearing WUA under Alternative 4 is similar to the No Action Alternative throughout the fry rearing period of December through March (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The results during these four months show little variation in the third quartile of the WUA distributions. This occurs because the fry rearing WUA curves peak at the lowest flows encountered in the river (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and Keswick Dam flow releases are frequently low during these months in critically dry years when Shasta Reservoir is operated to rebuild storage volume (Table O-266). The first quartile is much wider because a greater range of flows affect the fry rearing WUA values below the median.

The results of the fall-run Chinook salmon fry rearing habitat analysis suggest that Alternative 4 in comparison to the No Action Alternative may have a negligible (less than 1%) increase and/or decrease in estimated fry rearing habitat in all water year types and no large increases or decreases in estimated habitat on a monthly scale.

Fall-run Chinook Salmon: Juvenile Rearing Habitat Analyses

Under Alternative 4, mean juvenile rearing WUA increases in above normal, dry, and critically dry water year types and decreases in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated juvenile rearing habitat between Alternative 4 and the No Action Alternative is a 2% increase in critically dry water year types. The largest reduction in estimated juvenile rearing habitat between Alternative 4 and the No Action Alternative is a 0.7% decrease in below normal water year types.

The monthly median value of fry rearing WUA under Alternative 4 is similar from February through June (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The fry rearing WUA values under the modeled alternatives are similar across the months of February and March, and gradually decrease until the lowest estimated values in June. As discussed previously for fry rearing WUA, the high WUA values with low variability in the third quartile for February and March result from the peaking of the WUA curve at the lowest flows (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*) and frequent low Keswick Dam flow releases during these months to build Shasta Reservoir storage (Table O-266). The wide range of values in the first quartile of these months reflects the high frequency and variability of higher flows in these wet months. The lowest juvenile rearing WUA values in June result from releases in the summer months above 10,000 cfs and estimated peak juvenile rearing at flows below 5,000 cfs.

The results of the fall-run Chinook salmon juvenile rearing habitat analysis suggest that Alternative 4 compared to the No Action Alternative may have a minor (less than 2%) increases and/or decrease in estimated juvenile rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in the mainstem upper Sacramento River.

Fall-run Chinook Salmon: Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Alternative 4 shows a large but variable increase in stranding of fall-run Chinook salmon fry from critically dry to wet water year types, with a minor reduction in stranding from dry to below normal water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Fall-run Chinook salmon fry rearing occurs primarily during winter and early spring. Alternative 4 shows the highest median stranding in February and lowest median stranding in March, with intermediate levels in December and January (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). The higher mean stranding levels for fall-run fry during February and wet water year types likely results from periodic storms and high runoff that produce increased variability of flow. Mean fall-run fry stranding under Alternative 4 is lower than that under the No Action Alternative in all water year types, ranging from 7.2% lower in wet water years to 0.8% lower in critically dry water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, fall-run Chinook salmon juvenile stranding for fry is lower under Alternative 4, than under the No Action Alternative.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 247 for Keswick Dam, Table 248 for Red Bluff Diversion Dam, and Table 249 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 251 for Keswick Dam, Table 251 for Red Bluff Diversion Dam, and Table 253 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F

juvenile pathogen virulence threshold during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 255 for Keswick Dam, Table 256 for Red Bluff Diversion Dam, and Table 257 for Hamilton City.

Results for the three analyses are summarized in Table O-76. Table O-76, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with favorable results at all three locations (Table O-76). There were zero to two combinations (0% to 10.0%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were zero to two combinations (0% to 10.0%) with favorable results depending on location. There would be zero to two combination (0% to 10.0%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 4 on fall-run Chinook salmon juvenile rearing and emigration.

Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

Fall-run Chinook Salmon: Summary

The change in seasonal operations between Alternative 4 and the No Action Alternative are expected to result in minor increase and/or decrease on fall-run Chinook salmon fry and juvenile rearing habitat. Under Alternative 4, flows would be similar to the No Action Alternative in all water year types. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. Alternative 4 would cause beneficial and adverse water temperature-related impacts to fall-run Chinook salmon juvenile rearing and emigration in the Sacramento River.

Late Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under Alternative 4, mean fry rearing WUA increase in above normal and critically dry water year types and decrease in all other water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 1.9% increase in critically dry water year types. The largest reduction in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 0.3% decrease in below normal water year types.

The monthly median value of fry rearing WUA under Alternative 4 is similar to the No Action Alternative throughout the fry rearing period, March through June (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The fry rearing median WUA values under the modeled alternatives are similar across the months of May and June, and highest in March. The lower fry

rearing WUA values in May and June result from releases in the summer months above 7,000 cfs (Table O-266) and estimated peak fry rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the late fall-run Chinook salmon fry rearing habitat analysis suggest that Alternative 4 compared to the No Action Alternative may have a minor (less than 2%) increase and/or decrease in estimated fry rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in the mainstem upper Sacramento River.

Late Fall-run Chinook Salmon: Fry Stranding Analysis

The analysis of juvenile stranding is focused on fry because they are expected to be more vulnerable to stranding than the older juveniles, who are stronger swimmers. Mean stranding of late fall-run fry Chinook salmon under Alternative 4 shows minor and inconsistent variation with water year type; wet years have the highest stranding and dry years the lowest, with stranding in critically dry years similar to stranding in below normal and above normal water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Late fall-run Chinook salmon fry rearing occurs primarily during spring. Alternative 4 shows the highest median stranding in March, the lowest stranding in May, and similar stranding in April and June (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*). Mean fry stranding of late fall-run Chinook salmon is lower for all water year types under Alternative 4 than under the No Action Alternative. The reductions range from 1.0% for above normal water years to 21.8% for dry water years (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*).

Overall, late fall-run Chinook salmon juvenile stranding for fry is lower under Alternative 4 as compared to the No Action Alternative for all water year types and is much lower for dry water years.

Late Fall-run Chinook Salmon: Juvenile Rearing Habitat Analysis

Under Alternative 4, mean juvenile rearing WUA increases in all water year types compared to the No Action Alternative (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). The largest increase in estimated fry rearing habitat between Alternative 4 and the No Action Alternative is a 5.7% increase in critically dry water year types. There are no anticipated reductions in mean juvenile rearing WUA under Alternative 4 in comparison to the No Action Alternative.

The monthly median value of juvenile rearing WUA under Alternative 4 is similar to the No Action Alternative throughout the juvenile rearing period, May through September (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*). During the juvenile rearing period, the median WUA values steadily decline from May to the lowest median WUA values in July. The lower juvenile rearing WUA values in June and July result from releases in the summer months above 7,000 cfs (Table O-266) and estimated peak juvenile rearing at flows below 5,000 cfs (Attachment O.3, *Sacramento River Weighted Usable Area Analysis*).

The results of the late fall-run Chinook salmon juvenile rearing habitat analysis suggest that Alternative 4 compared to the No Action Alternative may have a minor (less than 6%) increase in estimated juvenile rearing habitat across all water year types and no large increases or decreases in estimated habitat on a monthly scale in the mainstem upper Sacramento River.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 279 for Keswick Dam, Table 280 for Red Bluff Diversion Dam, and Table 281 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 283for Keswick Dam, Table 284 for Red Bluff Diversion Dam, and Table 285 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 287 for Keswick Dam, Table 288 for Red Bluff Diversion Dam, and Table 289 for Hamilton City.

Results for the three analyses are summarized in Table O-77. Table O-77, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 55.4°F to 68°F juvenile optimum temperature range, there were zero to two month-water year type combinations (0% to 3.6% of total combinations during the period) with favorable results depending on location (Table O-77). There were zero to five combinations (0% to 9.1%) with unfavorable results depending on location. For the 75.2°F UILT for rearing and migrating juveniles, there would be no combinations with either favorable or unfavorable results at any location. For the 59.9°F juvenile pathogen virulence threshold, there were one to seven combinations (1.8% to 12.7%) with favorable results depending on location. There would be zero to three combinations (0% to 5.5%) with unfavorable results depending on location. These results suggest that there would be positive and negative water temperature-related effects of Alternative 4 on late fall-run Chinook salmon juvenile rearing and emigration.

Late Fall-run Chinook Salmon: Sacramento River Pulse Flows

There may be unintentional adverse impacts of spring pulse flows on fry stranding and predation from sudden drops in flow. There may be beneficial impacts from decreased travel time for juvenile outmigration.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in the Sacramento River between Alternative 4 and the No Action Alternative are expected to have minor adverse impacts on late fall-run Chinook salmon fry and juvenile rearing habitat. Under Alternative 4, flows would be similar to the No Action Alternative in all water year types and so would have similar impacts to fry and juvenile rearing habitat. The frequency of fry stranding would be similar to the No Action Alternative with minor increases and decreases in stranding. Fry stranding may occur following spring pulse flow events. There may be decreased travel times for juvenile outmigration during spring pulse flow events. Alternative 4 would cause beneficial and adverse water temperature-related impacts to late fall-run Chinook salmon juvenile rearing and emigration in the Sacramento River.

Adult Upstream Migration and Holding

Fall-run Chinook salmon migrate upstream past RBDD on the Sacramento River from July to December, and late fall-run Chinook salmon migrate upstream past RBDD from October through December (National Marine Fisheries Service 2009a). Adult late fall-run Chinook salmon typically hold in the river for one month to three months before spawning, while fall-run Chinook salmon generally spawn shortly after entering freshwater. See Section O.1.3.2 for additional information.

Potential Changes to Fall-run and Late Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

During the July through December period of fall-run and late fall-run Chinook salmon adult migration and holding, the mean monthly flows under Alternative 4 at Sacramento River below Keswick Dam, below RBDD, and at Hamilton City would mostly vary between being similar to moderately higher (up to 18%) in October, November and December in dry and critically dry water years compared to the No Action Alternative. However, during critically dry water years in July and August, there would be minor decreases in flow at these same locations. Flows at Wilkins Slough suggest decreases July through October for some water year types and increases October through December and April.

Expected flow values are at their lowest between July and December of critically dry years in December below Keswick Dam (~3,400 cfs), in October below Red Bluff Diversion Dam (~5,200 cfs), in September at Wilkins Slough (~3,250 cfs), and in October at Hamilton City (~4,600 cfs)(Tables O-266 through O-269). Flows at in the Sacramento River under Alternative 4 would be high enough (> 3,250 cfs) to allow upstream passage.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 227 for Keswick Dam, Table 228 for Red Bluff Diversion Dam, and Table 229 for Hamilton City. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 231 for Keswick Dam, Table 232 for Red Bluff Diversion Dam, and Table 233 for Hamilton City.

Results are summarized in Table O-78. Table O-78, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 37.9°F to 68°F successful adult migration range analysis, there were zero to two month-water year type combinations (0% to 6.7% of total combinations during the period) with favorable results depending on location (Table O-78). There were zero to one combinations (0% to 3.3%) with unfavorable results depending on location. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to five combinations (0% to 16.7%)

with favorable results and zero to one combinations (0% to 3.3%) with unfavorable results depending on location. These results suggest that there would be positive effects of Alternative 4 on water temperature conditions for fall-run Chinook salmon adult migration and holding in the Sacramento River.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 259 for Keswick Dam, Table 260 for Red Bluff Diversion Dam, and Table 261 for Hamilton City. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 262 for Keswick Dam, Table 263 for Red Bluff Diversion Dam, and Table 264 for Hamilton City.

Results are summarized in Table O-79. Table O-79, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 37.9°F to 68°F successful adult migration range analysis, there were zero to two month-water year type combinations (0% to 5.0% of total combinations during the period) with favorable results depending on location (Table O-79). There were no combinations (0%) with unfavorable results at all locations. For the 59.9°F adult pathogen virulence threshold analysis, there would be zero to five combinations (0% to 12.5%) with favorable results depending on location and zero to one combinations (0% to 2.5%) with unfavorable results at all locations. These results suggest that there would be positive effects of Alternative 4 on water temperature conditions for late fall-run Chinook salmon adult migration and holding in the Sacramento River.

Sacramento River Pulse Flows

Fall-run and late fall-run adult migration is outside the spring pulse flow period.

Summary

Under Alternative 4, conditions for adult fall-run and late fall-run Chinook salmon caused by water temperatures for successful migration are expected to be similar to the No Action Alternative, but with some more favorable conditions at Hamilton City. Below Keswick Dam and RBDD, fall-run and late fall-run Chinook salmon migrating adults would be exposed to more favorable conditions with respect to pathogen virulence. Migrating adult fall-run and late fall-run Chinook salmon would be experience both adverse and beneficial impacts from flow under Alternative 4 compared to the No Action Alternative.

O.7.14.2 Clear Creek

Spawning and Egg Incubation

Fall-run Chinook salmon typically spawn in Clear Creek from late September through early December, (Earley et al. 2013). Fall-run typically emerge from the gravel in December through March. Timing of peak late-fall spawning in the Sacramento River, January through April, was used as a proxy for Clear Creek. Late fall-run incubation and emergence is estimated to occur from March through June.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Spawning Habitat—Flow Analysis

Under Alternative 4, mean spawning WUA increases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The largest increase in estimated spawning habitat is a 5% increase in critically dry water year types. There are no anticipated reductions in mean spawning WUA under Alternative 4 in comparison to the No Action Alternative.

The mean values of spawning WUA by month are higher in November and December and lower in October under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the three months, December is expected to have the highest spawning WUA values under Alternative 4.

The spawning habitat analysis indicates that Alternative 4 may have a minor to moderate beneficial effect (1.7-5% increase) in fall-run Chinook salmon estimated spawning habitat in Clear Creek across all water year types when compared to the No Action Alternative.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 237 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during October through January are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 240 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during December through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 243 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-80. Table O-80, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 42.1°F to 55°F spawning initiation range analysis, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-80). For the 59.9°F

pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were zero (0%) combinations with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be no water temperature-related effects of Alternative 4 on fall-run Chinook salmon spawning and egg/alevin incubation in Clear Creek.

Fall-run Chinook Salmon: Summary

Results suggest there may be a beneficial impact of seasonal operations on fall-run Chinook salmon spawning and egg incubation in Clear Creek based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows may have a beneficial impact on spawning habitat. There would be no impacts caused by water temperature conditions on spawning initiation, pathogen virulence, and egg incubation and fry emergence.

Late Fall-run Chinook Salmon: CalSim 3 Flows

For the period of late-fall run Chinook salmon spawning and egg incubation (January through June), there would be both adverse and beneficial impacts below Whiskeytown Dam under Alternative 4 compared to the No Action Alternative. Average flow among all water year types during this period would substantially increase in January (35%), March (27%), April (15%) and May (36%) but have a moderate decrease in February (10%) and substantially decrease in June (31%) (Table O-275).

Using peak spawning flows of 300-350 cfs from the fall-run Chinook salmon WUA curves as a proxy for potential late-fall-run Chinook salmon spawning habitat, changes under Alternative 4 suggest that when averaged across all water year types, flows would increase favorable spawning areas. Even with the slight decrease in average flows in February, flows would still remain above around 300 cfs on average across all water year types. There would be a substantial increase in spawning habitat available for late fall-run Chinook salmon as a result of flows in Clear Creek.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 269 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold during January through April are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 272 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F range for egg incubation and fry emergence during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 275 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-81. Table O-81, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 42.1°F to 55°F range for spawning initiation temperature analysis, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results below Whiskeytown Dam (Table O-81). For the 59.9°F pathogen virulence threshold, there were no month-water year type combinations (0%) with favorable or unfavorable results below Whiskeytown Dam. For the 42.8°F to 56°F range for egg incubation and fry emergence, there were no month-water year type combinations (0%) with favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on late fall-run Chinook salmon spawning and egg incubation in Clear Creek.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 4 and the No Action Alternative is expected to have primarily beneficial effects on late-fall-run Chinook salmon spawning and egg incubation. Under Alternative 4, changes in flows provide mostly substantially beneficial conditions; however, flows in June create an adverse impacts to late incubation.

Juvenile Rearing and Emigration

The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, mostly between January through June. Late fall-run Chinook salmon juveniles typically enter the ocean after 7 to 13 months of rearing in freshwater, generally between October and February (Moyle 2002).

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: Fry Rearing Habitat Analysis

Under Alternative 4, mean fry rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean fry rearing WUA under Alternative 4 in comparison to the No Action Alternative. The greatest reduction in estimated fry rearing habitat is a 2.3% decrease in dry water year types under Alternative 4 in comparison to the No Action Alternative.

The mean values of fry rearing WUA by month are slightly lower under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). The four fry rearing months are expected to have similar fry rearing WUA values.

The results of the fry rearing habitat analysis indicate that Alternative 4 in comparison to the No Action Alternative may have a minor adverse impact (less than 3% decrease) in estimated fall-run Chinook salmon fry rearing habitat across all water year types in Clear Creek.

Fall-run Chinook Salmon: Juvenile Rearing Habitat Analyses

Under Alternative 4, mean juvenile rearing WUA decreases in all water year types in comparison to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). There are no anticipated increases in mean juvenile rearing WUA under Alternative 4 in comparison to the No Action Alternative. The largest reduction in estimated juvenile rearing habitat between Alternative 4 and the No Action Alternative is an 8.4% decrease in critically dry water year types. On average across all water year types, there is a 4.2% reduction in estimated juvenile rearing habitat under Alternative 4.

The mean values of juvenile rearing WUA by month are lower June through September and higher in May under Alternative 4 compared to the No Action Alternative (Attachment O.1, *Clear Creek Weighted Usable Area Analysis*). Out of the five months, May and June are expected to have the highest juvenile rearing WUA values.

The results of the juvenile rearing habitat analysis indicates that Alternative 4 in comparison to the No Action Alternative may have a minor to moderate adverse effect (up to 8.4% decrease) in fall-run Chinook salmon juvenile rearing habitat depending on the water year type.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 250 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F juvenile UILT during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 254 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F juvenile pathogen virulence threshold during March through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 258 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-82. Table O-82, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-82). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F juvenile pathogen virulence threshold, there were no month-water year type combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Fall-run Chinook Salmon: Summary

Under Alternative 4, changes in flows are expected to have a minor decrease in estimated fall-run Chinook salmon fry rearing habitat across all water year types in Clear Creek. Additionally, the results of the juvenile rearing habitat analysis suggests that Alternative 4 may have an adverse impact compared to the No Action Alternative from decreased juvenile rearing habitat. Potential water temperature-related impacts (growth, smoltification, predation, and pathogen virulence) would be similar to the No Action Alternative on fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Late Fall-run Chinook Salmon: CalSim 3 Flows

For the period late-fall juvenile rearing and emigration CalSim 3 modeling indicates that both negative and beneficial effects may occur below Whiskeytown Dam under Alternative 4 compared to the No Action Alternative. Average flow released would increase November through January and decrease June through October. The exception is during a critically dry water year during October with an increase of 15% (Table O-275). The largest decrease under Alternative 4 compared to the No Action Alternative occur June through August (an average of a 27% reduction among all water year types). A 31% reduction in average flow in June from 303 cfs to 208 cfs may have an adverse impact of rearing and emigration. Under Alternative 4 compared to the No Action Alternative, when all water year type simulations are averaged, flow released would increase November through January and March through May, and decrease in February and June through October

Under Alternative 4 from March through September during juvenile rearing periods for late-fall run Chinook salmon, flows would moderately increase from March to May (average of 31% across all water year types), but moderately decrease from June -September (average of 27%). Using the fall run WUA curves as a proxy for the late-fall run, optimal flows for maximum late-fall run juvenile rearing habitat is 300-400 cfs. The only month under Alternative 4 with flow within this range is February. CalSim 3 projects that under Alternative 4, late-fall run Chinook salmon juvenile rearing and emigration in Clear Creek would see both positive and negative impacts compared to the No Action Alternative, with the majority of months during the March through September rearing period having flows below the likely optimal range.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the analysis assessing the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 282 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the 75.2°F juvenile UILT during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 286 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the 59.9°F juvenile pathogen virulence threshold during April through February are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 290 for Clear Creek below Whiskeytown Dam.

Results for the three analyses are summarized in Table O-83. Table O-83, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 55.4°F to 68°F juvenile optimum temperature range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-83). For the 75.2°F UILT for rearing and migrating juveniles, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. For the 59.9°F juvenile pathogen virulence threshold, there were no month-water year type combinations (0%) with either favorable or unfavorable results ts below Whiskeytown Dam. These results suggest that there would be

negligible water temperature-related effects of Alternative 4 on late fall-run Chinook salmon juvenile rearing and emigration in Clear Creek.

Late Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 4 and the No Action Alternative is expected to have both beneficial and adverse impacts on late fall-run Chinook salmon. An increase in flows would occur from March through May, a substantial beneficial impact, but there would be decreases from June through October, an adverse impact. There would be negligible water temperature-related impacts of Alternative 4 on late fall-run Chinook salmon rearing and emigration in Clear Creek.

Adult Upstream Migration and Holding

Fall-run Chinook salmon may arrive at Clear Creek before spawning from July through early December. Adult late fall-run Chinook salmon migrate and arrive slightly later and do not need to hold and mature before spawning from November into January.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

Fall-run Chinook Salmon: CalSim 3 Flows

Average flows released to Clear Creek from Whiskeytown Dam would be substantially lower from July through October (up to 25%), and substantially higher from November and December (up to 30%; Table O-275). For the period of fall and late-fall adult migration and holding (July through December), there would be both substantial adverse and beneficial effects to fall-run Chinook salmon in Clear Creek under Alternative 4 compared to the No Action Alternative.

Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature outside the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 230 for Clear Creek below Whiskeytown Dam. Full results of the percent of months with water temperature above the 59.9°F adult pathogen virulence threshold analysis during July through December are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 234 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-84. Table O-84, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 37.9 F to 68°F successful adult migration range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-84). For the 59.9°F adult pathogen virulence threshold, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on fall-run Chinook salmon adult upstream migration and holding in Clear Creek.

Fall-run Chinook Salmon: Summary

The change in seasonal operations in Clear Creek between Alternative 4 and the No Action Alternative is expected to have adverse impacts and moderate to l beneficial impacts to fall-run Chinook salmon. Flows would decrease from July through October resulting in substantially adverse impacts, but flows would substantially increase in November and December, resulting in a substantial beneficial impact. There would be no water temperature impacts (adult migration and pathogen virulence) of Alternative 4 on fall-run Chinook salmon adult upstream migration and holding in Clear Creek.

Late Fall-run Chinook Salmon: CalSim 3 Flows

During the periods of late-fall run Chinook salmon adult migration (November through January), flows would be increased by an average of 27% among all water year types when compared to the No Action Alternative. The largest increase is in January with a 35% increase in average flows (222 cfs to 301cfs)(Table O-275). There would be a substantial increase in suitable migration and holding habitat available for adult late fall-run Chinook salmon as a result of flows in Clear Creek.

Late Fall-run Chinook Salmon: Water Temperature Analysis

Full results of the percent of months with water temperature above the 37.9°F to 68°F successful migration range analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 262 for Clear Creek below Whiskeytown Dam. Full results of the percent of months with water temperature outside the 59.9°F adult pathogen virulence threshold analysis during August through March are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 266 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-85. Table O-85, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 37.9°F to 68°F successful adult migration range, there were zero month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-85). For the 59.9°F adult pathogen virulence threshold, there were zero combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible effects of Alternative 4 on late fall-run Chinook salmon adult upstream migration and holding in Clear Creek.

Late Fall-run Chinook Salmon: Summary

Under Alternative 4, flows would be increased from November through January so there may be a beneficial impact of seasonal operations on late-fall-run Chinook salmon adult migration in Clear Creek based on analyses of simulated flows under Alternative 4 in comparison to the No Action Alternative. Water temperature results suggest that there would be negligible water temperature-related impacts from Alternative 4 on late fall-run Chinook salmon adult upstream migration and holding in Clear Creek

O.7.14.3 Lower American River

Spawning and Egg Incubation

Spawning occurs from about mid-October through early February, with peak spawning from mid-October through December. Chinook salmon spawning occurs within an 18-mile stretch from Paradise Beach to Nimbus Dam; however, most spawning occurs in the uppermost 3 miles (California Department of Fish and Wildlife 2012a). Chinook salmon egg and alevin incubation occurs in the lower American River from about mid-October through April. There is high variability from year to year; however, most incubation occurs from about mid-October through February.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Spawning Habitat—Flow Analysis

Under Alternative 4, fall-run Chinook salmon mean spawning WUA varies modestly among water year types, with no evident trend (Attachment M.3, *American River Weighted Usable Area Analysis*). The highest means are for above normal and below normal water year types and the lowest is for wet water years. Mean spawning WUA is lower under Alternative 4 than under the No Action Alternative for all water year types. The largest reduction is 5.5% for critically dry water years. The other reductions range between 1.1% lower and 0.5% lower (Attachment M.3, *American River Weighted Usable Area Analysis*). For all three months of the fall-run Chinook salmon spawning season, estimated median spawning WUA under Alternative 4 is similar to that under No Action Alternative (Attachment M.3, *American River Weighted Usable Area Analysis*). Spawning WUA for all alternatives is higher in October than in November or December because flows, on average, are lower in October (Table O-277). The fall-run Chinook salmon spawning WUA curve (Attachment M.3, *American River Weighted Usable Area Analysis*) peaks at relatively low flows (below 3,000 cfs).

Overall, fall-run Chinook salmon spawning WUA is similar under Alternative 4 to that under the No Action Alternative.

Redd Dewatering

The results of the analysis for fall-run Chinook salmon under Alternative 4 indicate that mean redd dewatering potential is greatest in wet water years and lowest in critically dry years (Attachment M.1, *American River Redd Dewatering Analysis*). The higher redd dewatering potential in wet water years reflects a greater frequency of large flow fluctuations in this water year type. Redd dewatering is higher under Alternative 4 than the No Action Alternative for all water year types, except for an 8.6% reduction in critically dry water years (Attachment M.1, *American River Redd Dewatering Analysis*). The largest increase is 38.9% for above normal water years. It should be noted, however, that the absolute difference in percent of redds dewatered between Alternative 4 and the No Action Alternative ranges from a 0.6% reduction in critically dry water years to a 4.4% increase in above normal water years . For the individual months of fall-run Chinook salmon spawning in the lower American River, redd dewatering potential increases from spawning in October to that in December, reflecting the increasingly higher flow levels and fluctuations over this period (Attachment M.1, *American River Redd Dewatering Analysis*).

Overall, redd dewatering potential is higher under Alternative 4 than the No Action Alternative, except for slightly lower redd dewatering for critically dry years. Differences are consistently much smaller on an absolute difference scale.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 42.1°F to 55°F range for spawning initiation during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 63 for Hazel Avenue and Table 64 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult spawning pathogen virulence threshold during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 65 for Hazel Avenue and Table 66 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence during October through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 67 for Hazel Avenue and Table 68 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during October through March are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 69 for Hazel Avenue and Table 70 for Watt Avenue.

Results for the four analyses are summarized in Table O-86. Table O-86, as described in Section O.4.12.3.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 42.1°F to 55°F range for spawning initiation, there were zero month-water year type combinations (0%) with favorable results at both Hazel and Watt Avenue(Table O-86). There were two and zero combinations (5.7% and 0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for spawning adults, there were zero combinations (0%) with favorable and unfavorable results at both Hazel and Watt Avenue. For the 42.8°F to 56°F range for egg incubation and fry emergence analysis, there were one and zero month-water year type combinations (3.3% and 0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero and two month-water year type combinations (0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 59.9°F fry pathogen virulence threshold analysis, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watts Avenue.

These results suggest that there would be positive (3.3%) and negative (5.7% to 6.7%) water temperature-related effects of Alternative 4 on fall-run Chinook salmon spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Overall, seasonal operations in the lower American River on fall-run Chinook salmon spawning based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative are similar or have negligible differences. Fall-run Chinook salmon

spawning WUA is predicted to be similar under Alternative 4 to that under the No Action Alternative. Water temperature impacts are predicted to have both beneficial and adverse impacts at Hazel Avenue and Watt Avenue.

Juvenile Rearing and Emigration

Chinook salmon fry emergence occurs from January through mid-April, and juvenile rearing extends from January to about mid-July (Williams 2001). Most fall-run Chinook salmon out-migrate from the lower American River as fry from December to July; out-migration peaks in February and March (Snider and Titus 2002; Pacific States Marine Fisheries Commission 2014).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

For the period of juvenile rearing and emigration (December through July), CalSim 3 modeling indicates that flow released in the lower American River below Nimbus Dam under Alternative 4 compared to the No Action Alternative would generally be similar or negligible with both moderate adverse and beneficial effects during a critically dry year (Table O-277). In a critically dry year it is predicted that flows would decrease from February through March by around 5-23%, but flow would be increased in December, January, and July, 13%, 7%, and 14% respectively.

For the period of juvenile rearing and emigration (December through July) in the lower American River at H Street, CalSim 3 modeling of Alternative 4 compared to the No Action Alternative indicates that at H Street flow releases would generally be similar or negligible with both adverse and beneficial effects during a critically dry year (Table O-278). In a critically dry year it is predicted that flows would decrease from February through May by around 6-24%, but flow would be increased in December, January, and July, 13%, 8% and 16% respectively.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 71 for Hazel Avenue and Table 72 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F upper incipient lethal temperature (UILT) for juveniles during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 73 for Hazel Avenue and Table 74 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration during January through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 75 for Hazel Avenue and Table 76 for Watt Avenue.

Results for the three analyses are summarized in Table O-87. Table O-87 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability, there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Hazel and Watt Avenue, respectively (Table O-87). There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75.2°F upper incipient lethal temperature (UILT) for juveniles, there were zero combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration, there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue. There was one month-water year type combinations (4.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. These results suggest that Alternative 4 would have positive (4% favorable) and negative (4% unfavorable) water temperature-related effects on fall-run Chinook salmon juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

CalSim 3 modeling at on the lower American River below Nimbus Dam and at H Street have similar results to each other indicating that on average there would be negligible differences in flows during juvenile rearing an emigration, the exception is during a critically dry year when there is both adverse and beneficial impact with increase flows in December and July and reduced flows February -April. Water temperature modeling results are similar with occasional beneficial and adverse water temperature-related impacts on fall-run Chinook salmon juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Adult Upstream Migration and Holding

Adult fall-run Chinook salmon enter the lower American River from about mid-September through January, with peak migration from approximately mid-October through December (Williams 2001).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

CalSim 3 Flows

For the period of adult migration and holding (September through January) in the lower American River below Nimbus Dam, CalSim 3 modeling indicates that flow released from Folsom Reservoir Storage under Alternative 4 compared to the No Action Alternative would generally be similar or negligible with both adverse and beneficial effects during a critically dry year (Table O-277). In a critically dry year, it is predicted that flows would decrease September through November 8%-12% but flow would be increased in December by 8%.

For the period of adult migration and holding (September through January) in the lower American River at H Street, CalSim 3 modeling of Alternative 4 compared to the No Action Alternative indicates that at H Street flow releases would generally be similar or negligible with both adverse and beneficial effects during a critically dry year (Table O-278). In a critically dry year, it is predicted that flows would decrease September through November 10%-15% a moderate adverse effect, but flow would be increased in December by 8%.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 59 for Hazel Avenue and Table 60 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration during June through December are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 61 for Hazel Avenue and Table 62 for Watt Avenue.

Results for the two analyses are summarized in Table O-88. Table O-88, as described in Section O.4.12.3.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 37.9°F to 68°F successful migration range for adult fall-run Chinook salmon under, there were four and two month-water year type combinations (11.4% and 5.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-88). There were four and two month-water year type combination (11.4% and 5.7%, respectively) with unfavorable results at both Hazel Avenue and Watt Avenue, respectively. For the 59.9°F pathogen virulence threshold for adult migration, there were zero month-water year type combinations (0%) with favorable and unfavorable results at both Hazel Avenue and Watt Avenue. These results indicate that Alternative 4 would have positive (5.7% to 11.4% favorable) and negative (5.7% to 11.4% unfavorable) water temperature-related effects to fall-run Chinook salmon upstream migration and holding in the lower American River at Hazel Avenue and Watt Avenue.

Summary

CalSim 3 modeling on the lower American River below Nimbus Dam and at H Street have similar results indicating that on average there would be negligible differences in flows during adult migration and holding with the exception of during a critically dry year when there is both a moderate adverse and beneficial impact with increase flow in December but reduced flow from September through November. Water temperatures under Alternative 4 would have both beneficial and adverse impacts to fall-run Chinook salmon adult upstream migration in the lower American River relative to the No Action Alternative.

O.7.14.4 San Joaquin River

Fall-run Chinook salmon adults migrate upstream through the San Joaquin River at Vernalis between September and November. Juvenile fall-run Chinook salmon migrate downstream past Vernalis primarily January through May. See Section O.1.8.1 for additional information.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Changes in seasonal operations would result in minimal changes in flows in the San Joaquin River at Vernalis. Under the Alternative 4, average flows released at on the San Joaquin River near Vernalis would be similar (below 5%) to the No Action Alternative (Table O-281), except in June through September in critically dry water years when there would be minor to moderate increases in flows (6% to 22%).

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on fall-run Chinook salmon in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

There would be minimal impacts to migrating adults and juvenile fall-run Chinook salmon in the San Joaquin River at Vernalis. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.7.14.5 Bay-Delta

Juvenile Rearing and Emigration

Most fall-run Chinook salmon fry rear in freshwater from December through June, with out-migration as smolts occurring primarily from January through June, with presence in the Delta in December through July. In general, fall-run Chinook salmon fry abundance in the Delta increases following high winter flows. Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. Late fall-run Chinook salmon outmigrants may be found in the Delta between December and April. See Section O.1.9.1 for additional information.

Potential Changes to Fall-run / Late Fall-run Chinook Salmon ESU from Seasonal Operations

<u>Zone of Influence</u>

Differences in hydrology under Alternative 4 compared with the No Action Alternative may have effects on the spatial extent of influence of exports under CVP and SWP diversions. With incremental decreases in OMR under Alternative 4 and the No Action Alternative, proportional overlap at these three locations decreases, with more subtle changes along the San Joaquin River at Jersey Point compared to Turner Cut and Old River at Middle River. Effects of pumping are smallest at the most upstream location (San Joaquin River at Jersey Point), and greater at Turner Cut, which is less influenced by riverine flow and thus more susceptible to changes in pumping. For a detailed description of how flows under Alternative 4 may impact the proportional overlap at Turner Cut, San Joaquin River at Jersey Point, and Old River at Middle River, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2, *Zone of Influence*).

<u>Flow into Junctions</u>

Differences in flow routing under Alternative 4 compared with the No Action Alternative may have effects on the flow into the Head of Old River and CVP junctions.

Under Alternative 4 in all OMR bins except -3,500, predicted proportion of flow entering the Central Valley Project is less than the No Action Alternative. Changes in predicted proportion of flow entering the CVP in OMR bins -3,500, -5,000, and <-5,500 was less than ± 0.0372, indicating a negligible difference between Alternative 4 and the No Action Alternative. However, in OMR bin -2,000 the change in predicted proportion of flow into CVP was -0.0676 indicating that slightly less flow will be routed into CVP under Alternative 4 than when compared to the No Action Alternative.

Under Alternative 4 in OMR bins -2,000 and <-5,500, predicted proportion of flow entering the HOR is less than the No Action Alternative. In OMR bins -3,500 and -5,000, the predicted proportion of flow entering the HOR is greater than the No Action Alternative. However, changes in predicted proportion of flow entering the HOR in all OMR bins was less than ± 0.026, indicating a negligible difference between Alternative 4 and the No Action Alternative.

For a detailed description of how flows under Alternative 4 may impact the flow at HOR and CVP, see Alternative 4, Sacramento River Winter-run Chinook Salmon ESU (Section O.7.8.2, *Flow into Junctions*).

Summary

Alternative 4 relative to the No Action is expected to influence flow into the HOR and CVP junctions due to differences in water management. Under Alternative 4, no change to possibly less flow into CVP under OMR -2,000; no change in flow into HOR under any OMR groupings. Impacts of pumping under both Alternative 4 and the No Action Alternative are smaller at the more upstream locations (e.g., San Joaquin River at Jersey Point) and greater at Turner Cut where there is less influence of riverine flow and thus more susceptible to changes in pumping (ZOI).

Potential Changes to Entrainment of Fall-run / Late Fall-run Chinook Salmon ESU

Differences in exports under Alternative 4 compared with the No Action Alternative may have effects on fall-run/ late fall-run Chinook salmon at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density model.

Fall-run Chinook Salmon: Salvage Density

Predictions from the salvage density model for fall-run Chinook salmon include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through July and all water year types under Alternative 4, was greater than predicted average monthly loss under the No Action Alternative. Predicted average monthly loss at Banks under Alternative 4, had a range from 29% higher for wet water year types to 77% higher for below normal water year types (Table O-89). Predicted average monthly loss of fall-run Chinook salmon at CVP Jones Pumping Plant for the months of November through August Alternative 4, was equal or higher than predicted average monthly loss under the No Action Alternative for all water year types except for dry water year types. The range of predicted loss for fall-run Chinook salmon at Jones under Alternative 4, compared to the No Action Alternative was from 1% lower in dry water year types to 4% higher for below normal water year types

(Table O-90). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Late Fall-run Chinook Salmon: Salvage Density

Predictions from the salvage density model for late fall-run Chinook salmon include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of late fall-run Chinook salmon at SWP Banks Pumping Plant for the months of December through April and all water year types Alternative 4 was lower than predicted average monthly loss under the No Action Alternative. Predicted average monthly loss at Banks under Alternative 4 had a range from 1% lower for critically dry water year types to 13% lower for dry water year types (Table O-91). Predicted average monthly loss of late fall-run Chinook salmon at CVP Jones Pumping Plant for the months of November through August under Alternative 4 was lower than predicted average monthly loss under the No Action Alternative for wet, below normal and dry water year types, predicted loss was higher for above normal and critically dry water year types. The range of predicted loss for late fall-run Chinook salmon at Jones Pumping Plant under Alternative 4 compared to the No Action Alternative was from 5% lower in wet water year types to 2% higher for above normal water year types (Table O-92). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Summary

The predicted monthly entrainment of fall-run Chinook salmon at Banks Pumping Plant is expected to be substantially increased under Alternative 4 compared to the No Action Alternative in all water year types, causing substantial impacts to fall-run Chinook salmon. The predicted monthly entrainment of fall-run Chinook salmon at the Jones Pumping Plant would be similar to the entrainment under the No Action in all water year types. Late fall-run Chinook salmon entrainment at Banks Pumping Plant would have increases and decreases but would be similar at Jones Pumping Plants under Alternative 4 compared with the No Action Alternative.

Potential Changes to Through Delta Survival of Fall-run / Late Fall-run Chinook Salmon ESU

Delta Passage Model

The DPM simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River and estimates survival to Chipps Island. For this application, only survival of fish entering the Delta from the Sacramento River are evaluated. The DPM uses available time-series data and values taken from empirical studies or other sources to parameterize model relationships and inform uncertainty, thereby using the greatest amount of data available to dynamically simulate responses of smolt survival to changes in water management. (Attachment I.6, *Delta Passage Model*). The major model functions in the DPM are listed under winter-run Chinook salmon (Section O.4.8.2).

The major model functions in the DPM are as follows.

- **Fall-run Chinook Salmon:** Under Alternative 4, in all water year types except critically dry and dry water years, predicted mean survival of fall-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). However, the change in mean predicted proportion survival to Chipps Island in all water year types is less than or equal to ± 0.002. There is not a substantial difference in predicted proportion of fall-run Chinook salmon surviving to Chipps Island between Alternative 4 and the No Action Alternative.
- **Late Fall-run Chinook Salmon:** Under Alternative 4, in all water year types except below normal and critically dry water years, predicted mean survival of late-fall-run Chinook salmon to Chipps Island is lower than when compared to the No Action Alternative (Attachment I.6, *Delta Passage Model*). The change in mean predicted survival to Chipps Island in all water year types less than or equal to ± 0.002. There is not a substantial difference in predicted proportion of late-fall-run Chinook salmon

Summary

Under Alternative 4, there would be changes in through Delta survival of both fall-run and late fall-run Chinook salmon through the Delta to Chipps Island compared to the No Action Alternative

O.7.14.6 Stanislaus River

Spawning and Egg Incubation

Peak spawning for fall-run Chinook salmon in the Stanislaus River typically occurs in November with roughly 7% of spawning occurring prior to November 1, and 2% prior to October 15. The few redds created during late September and early October are typically in the reach just below Goodwin Dam with spawning typically ending in December.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Spawning Habitat—Flow Analysis

The results for Alternative 4 show a consistent trend of reduction in mean spawning WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the shape of the fall-run Chinook salmon spawning WUA curves (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which show reduced WUA with increased flow, except at the lowest and highest flows (less than about 200 cfs to 500 cfs and greater than about 1,000 cfs, respectively). CalSim 3 mean monthly flows below Goodwin Dam, which is immediately upstream of the WUA study reach, are 200 cfs or above in all water year types, with flow generally increasing from critically dry to wet water years during all months of the October through December fall-run Chinook salmon spawning period, except December (Table O-279). The mean spawning WUA estimates for Alternative 4 are similar to those for the No Action Alternative, ranging from 2.7% lower in below normal water years to 0.4% higher in dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fall-run Chinook salmon spawning period, median spawning WUA under Alternative 4 is higher than the median under the No Action Alternative in November and December and is about the same in October (Attachment N.1, *Stanislaus River Habitat Availability Analysis*).

Overall, the results indicate that mean spawning WUA for fall-run Chinook are about the same for Alternative 4 and the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 42.1°F to 55°F range for spawning initiation during October through January are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 55 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F adult spawning pathogen virulence threshold during October through January are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 56 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 57 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F fry pathogen virulence threshold during December through March are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 58 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-93. Table O-93 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 42.1°F to 55°F range for spawning initiation there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge (Table O-93). For the 59.9°F adult spawning pathogen virulence threshold, there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 42.8°F to 56°F water temperature range for fall-run Chinook salmon egg incubation and fry emergence there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 59.9°F fry pathogen virulence threshold there were also no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge.

These results suggest that Alternative 4 would have negligible water temperature-related effects on fall-run Chinook salmon spawning and egg incubation.

Summary

Under Alternative 4 compared to the No Action Alternative, there are expected negligible impacts of seasonal operations in the Stanislaus River on fall-run Chinook spawning and egg incubation. The WUA and temperature model results indicate that mean spawning WUA for fall-run Chinook are about the same or would have negligible impacts under Alternative 4 compared to the No Action Alternative on fall-run Chinook salmon spawning and egg incubation. There would be similar conditions affecting spawning initiation, egg incubation and fry emergence, and pathogen virulence.

Juvenile Rearing and Emigration

Fall-run Chinook salmon juvenile rearing in the Stanislaus River typically occurs from January through May (Stanislaus River Fish Group 2004). Fry migration generally occurs from January through March, followed by smolt migration from April through May (Bureau of Reclamation 2012).

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

Rearing Habitat–WUA Flow Analyses

The results for fall-run Chinook salmon fry rearing WUA under Alternative 4 show a consistent trend from the highest mean rearing WUA in critically dry to the lowest in wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the fall-run Chinook salmon fry WUA curves, which show reduced WUA with increased flow, especially in the Orange Blossom Bridge and Riverbank reaches (Attachment N.1, *Stanislaus River Habitat Availability Analysis*), which are the longest river segments of the study. Mean fry rearing WUA under Alternative 4 is consistently higher than that under the No Action Alternative in all water year types, ranging from 2.7% higher in above normal water years to 7.2% higher in critically dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fry rearing period, fry rearing WUA is higher under Alternative 4 than under the No Action Alternative in all four months (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). The increase is especially large for February.

The results for juvenile rearing WUA under Alternative 4 shows little change in mean rearing WUA from critically dry to wet water year types (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Juvenile rearing WUA is higher under Alternative 4 than under the No Action Alternative for all water year types, ranging from 2.9% higher for wet water years to 5.5% higher for critically dry water years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the juvenile rearing period, the medians of juvenile rearing WUA are much lower in March than in other months (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Median juvenile rearing WUA is slightly higher under Alternative 4 than the No Action Alternatives in March, but there is little difference in the other months.

Overall, the results indicate that fry and juvenile rearing WUA for fall-run Chinook salmon is consistently but modestly higher under Alternative 4 than under the No Action Alternative.

Rearing Habitat—ASH Flow Analyses

The results of the Area of Suitable Habitat (ASH) analysis for fall-run Chinook salmon fry and juvenile rearing are quite different from the rearing WUA results described above. The mean ASH estimates vary strongly with water year type for both fry and juvenile fall-run Chinook salmon, consistently increasing from critically dry to wet years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). This pattern of variation reflects the overall relationship between flow and ASH for both life stages determined from modeling and field studies (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). Differences in fry and juvenile ASH between Alternative 4 and the No Action Alternative are moderate, which is consistent with the results of the rearing WUA analyses. For the fry, mean ASH is higher under Alternative 4

than the No Action Alternative for all water year types, ranging from 1.1% higher for wet years to 6.6% higher for critically dry water years. For the juveniles, mean ASH varies from 4.8% lower under Alternative 4 in below normal water years to 5.7% higher for critically dry years (Attachment N.1, *Stanislaus River Habitat Availability Analysis*). For the individual months of the fall-run Chinook salmon fry rearing period, median ASH under Alternative 4 relative to the No Action Alternative are higher in February, lower in April, and similar in March and May.

Overall, the results indicate that fry rearing ASH for fall-run Chinook salmon is somewhat higher under Alternative 4 than under the No Action Alternative, while juvenile rearing ASH is similar between the alternatives for all water year types combined.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 59 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 75.2°F upper incipient lethal temperature (UILT) for juveniles during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 60 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration during March through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 61 for Orange Blossom Bridge.

Results for the three analyses are summarized in Table O-94. Table O-94, as described in Section O.4.14.6, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 55.4°F to 68°F optimum temperature for juvenile growth, smoltification, and predation vulnerability there were two month-water year type combinations (10.0%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-94). For the 75.2°F upper incipient lethal temperature (UILT) for juvenile fall-run Chinook salmon there were no month-water year type combinations (0%) with favorable or unfavorable results at Orange Blossom Bridge. For the 59.9°F pathogen virulence water temperature threshold for fall-run Chinook salmon juvenile outmigration there was zero month-water year type combination (0.0%) with favorable results and one combination (5.0%) with unfavorable results at Orange Blossom Bridge. These results suggest that there would be positive water temperature-related effects of Alternative 4 on fall-run Chinook salmon juvenile rearing and emigration.

Summary

For the period of juvenile rearing and emigration of fall-run Chinook salmon in the Stanislaus River, CalSim 3 modeling under Alternative 4 compared to No Action Alternative suggest a mix of beneficial and adverse impacts may occur depending on water year type. The modeled median juvenile rearing WUA is slightly higher under Alternative 4 than the No Action Alternatives in March, but there is little difference in the other months. Fry rearing ASH for fall-run Chinook

salmon is somewhat higher under Alternative 4 than under the No Action Alternative a likely beneficial result. These results suggest that there would be beneficial impacts on fall-run Chinook salmon juvenile rearing and emigration. There would be similar conditions affecting spawning initiation, egg incubation and fry emergence, and pathogen virulence.

Adult Upstream Migration and Holding

Fall-run Chinook salmon adults generally migrate upstream from late September through December with peak migration from late October through early November in the Stanislaus River.

Potential Changes to Fall-run Chinook Salmon ESU from Seasonal Operations

For the period of adult migration and holding of fall-run Chinook salmon (September-December) in the Stanislaus River below Goodwin Dam, CalSim 3 modeling under Alternative 4 compared to No Action Alternative indicates that on average, among all water year types, only negligible differences in WUA would occur with a minor beneficial increase in December of 7% (Table O-279).

For the period of adult migration and holding of fall-run Chinook salmon (September-December) in the Stanislaus River at the mouth, CalSim 3 modeling under Alternative 4 compared to No Action Alternative indicates that on average, among all water year types, only negligible differences in WUA would occur with a minor beneficial increase in September of 5% on average and an increase of 29% in a critically dry water year (Table O-280).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 37.9°F to 68°F successful migration range during July through December are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 51 for Orange Blossom Bridge and Table 52 for above the confluence with the San Joaquin River. Full results of the analysis assessing the percent of months with water temperature above the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration during July through December are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 53 for Orange Blossom Bridge and 54 for above the confluence with the San Joaquin River.

Results for the two analyses are summarized in Table O-95. Table O-95, as described in Section O.4.14.6 reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was greater than 10%.

Under Alternative 4 for the 37.9°F to 68°F successful migration range there were no month-water year type combinations (0.0%) with favorable or unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-95). For the 59.9°F pathogen virulence water temperature threshold for adult fall-run Chinook salmon migration there was also no month-water year type combinations (0.0%) with favorable or unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River.

These results suggest that Alternative 4 would have negligible water temperature-related effects on fall-run Chinook salmon upstream holding and migration in the Stanislaus River at Orange Blossom Bridge and above the confluence of the San Joaquin River.

Summary

For the period of adult migration and holding of fall-run Chinook salmon (September-December) in the Stanislaus River, CalSim 3 modeling under Alternative 4 compared to No Action Alternative indicates that on average, among all water year types, only negligible differences would occur at both Goodwin Dam and the mouth. Additionally, the water temperature model results indicate there would be negligible impacts under Alternative 4 compared to the No Action Alternative at Orange Blossom Bridge and above the confluence of the San Joaquin River. There would be similar water temperature conditions affecting spawning initiation, egg incubation and fry emergence, and pathogen virulence.

O.7.15 White Sturgeon

O.7.15.1 Sacramento River

Spawning and Egg Incubation

Spawning occurs in deep water in the middle and lower Sacramento River from near Verona (~RM 80) to just upstream of Colusa (~RM 156) from late February to early June, peaking during March and April, (Section O.1.3.2.6, *White Sturgeon*). Because the incubation time for white sturgeon is so short, the peak impacts analysis period for incubating eggs is also considered to be March and April.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the March and April spawning and egg incubation period for white sturgeon, CalSim 3 estimates of mean monthly flows at Wilkins Slough under Alternative 4 range from about 4,200 cfs for April of critically dry water years to about 18,000 cfs for March of wet water years (Table O-268). Because white sturgeon spawn in deep pools, these flow levels are likely to be adequate for spawning and egg incubation, so no adverse effects are expected to result. Differences in flows between Alternative 4 and the No Action Alternative are small in both months (up to 1%), but flows are moderately higher (8%) for Alternative 4 in April of critically dry water years (Table O-268). It is concluded that Alternative 4 would have similar flow effects on white sturgeon eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 61°F upper limit for optimal egg incubation during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 291 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature above the 68°F upper limit for embryo hatching during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 292 for Hamilton City.

Results for the two analyses are summarized in Table O-96. Table O-96, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 61°F upper limit for optimal egg incubation, there were no month-water year type combinations (0.0%) with favorable and unfavorable results at Hamilton City (Table O-96). For the 68°F upper limit for embryo hatching, there were no combinations (0%) with favorable or unfavorable results at Hamilton City. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on white sturgeon spawning and egg incubation in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on spawning habitats due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have negligible water temperature-related impacts on spawning in the Sacramento River.

Larval and Juvenile Rearing and Emigration

The white sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 days post hatch (Heublein et al. 2017a, Deng et.al 2002). Therefore, since white sturgeon spawn from late February to early June, peaking in March and April, the larval period is considered to be March through June. Juvenile white sturgeon are believed to initiate a secondary dispersal (the primary dispersal occurring at the larval stage) in spring by actively swimming downstream during the night (Heublein et al. 2017a). The juvenile emigration period is considered to be April through July. Therefore, the effects analysis period for larvae and juvenile rearing and emigration is considered to be March through July.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the white sturgeon larval and juvenile rearing and emigration period, approximately March to July, CalSim 3 estimates of mean monthly flows at Wilkins Slough under Alternative 4 range from about 3,300 cfs for May of critically dry water years to about 18,000 cfs for March of wet water years (Table O-268). Differences in flows between Alternative 4 and the No Action Alternative are generally small in all four months of all water years (up to 5%), with a few exceptions. Flows would moderately decrease in July of critically dry years (up to 5%) (Table O-268). These flow levels are likely to be adequate for white sturgeon rearing and emigration; therefore, Alternative 4 would likely have a similar effect on larval and juvenile white sturgeon relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 66°F limit above which stress is observed in juvenile white sturgeon year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 293 for Hamilton City.

Results for the analysis are summarized in Table O-97. Table O-97, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 66.6°F stress limit for juvenile white sturgeon, there were three month-water year type combinations (5.0% of total combinations during the period) with favorable results and one combination (1.7%) with unfavorable results at Hamilton City (Table O-97). These results suggest that there would be negligible water temperature-related effects of Alternative 4 on white sturgeon larval and juvenile rearing and emigration in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on rearing and emigration habitats due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have negligible water temperature-related impacts on rearing and emigration in the Sacramento River.

Adult Upstream Migration and Holding

Adults ready for spawning likely move into the lower reaches of the Sacramento River during early winter to begin their upstream migration (Section O.1.3.2.6, *White Sturgeon*). Upstream migration appears to be rapid, with minimal holding time (Schaffter 1997, Heublein et al. 2017a). Based on rapid upstream migration, short egg incubation period, and larval presence in the Sacramento River; the adult upstream migration and holding period is considered to be December to February for this effects analysis.

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

During the white sturgeon adult upstream migration and holding period, approximately December to February, CalSim 3 estimates of mean monthly flows at Wilkins Slough under Alternative 4 range from about 6,400 cfs for January of critically dry water years to about 19,900 cfs for February of wet water years (Table O-268). CalSim 3 results indicate that differences in flows during December through February would generally be minimal (up to 5%) with Alternative 4 compared to the No Action Alternative (Table O-268). Therefore, Alternative 4 would have a similar effect on upmigrating and holding adult white sturgeon relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperature for adult white sturgeon during November through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 294 for Hamilton City.

Results for the analysis are summarized in Table O-98. Table O-98, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 77°F upper limit of suitable water temperature for adult white sturgeon, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results (Table O-98). These results suggest that there would be negligible water temperature-related effects of Alternative 4 on adult white sturgeon holding and migration in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on upstream migration and holding habitats. Alternative 4 relative to the No Action Alternative is expected to have negligible water temperature-related impacts on upstream migration and holding in the Sacramento River.

O.7.15.2 Lower American River

Limited quantitative information is available on the distribution and status of white sturgeon in the lower American River; however, small numbers of adults apparently use the lower American River, as evidenced by sturgeon report cards submitted to the CDFW by anglers in recent years (Section O.1.6.2.1, *Fish Evaluated in the Lower American River*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Adult white sturgeon have been reported by anglers in the lower American River during all months of the year, peaking in March-April and November-December (California Department of Fish and Wildlife 2023i). During all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 4 range from about 704 cfs for October of critically dry water years to about 12,284 cfs for February of wet water years (Table O-277). For the full simulation period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 6%) under Alternative 4 compared to the No Action Alternative (Table O-277).

During all months, CalSim 3 estimates of mean monthly flows at H Street under Alternative 4 range from about 583 cfs for October of critically dry water years to about 12,307 cfs for February of wet water years (Table O-277). For the full simulation period average, CalSim 3 results indicate that differences in flows during January through December would generally be minimal (up to 7%) under Alternative 4 compared to the No Action Alternative (Table O-277).

White sturgeon are not likely to be affected by changes in flow under Alternative 4 compared to the No Action Alternative due to their limited distribution in the lower American River.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F upper limit of suitable water temperatures for adult white sturgeon year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 77 for Hazel Avenue and Table 78 for Watt Avenue.

Results for the analysis are summarized in Table O-99. Table O-99, as described in Section O.4.15.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 77°F upper limit of suitable water temperatures for adult white sturgeon, there were zero month-water year type combinations (0%) with favorable results at Hazel Avenue and Watt Avenue (Table O-99). There were also zero month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue.

These results suggest that Alternative 4 would have no water temperature-related effects on non-spawning white sturgeon in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on white sturgeon habitat due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have no water temperature-related impacts on white sturgeon habitat in the lower American River.

O.7.15.3 San Joaquin River

Little is known about white sturgeon populations inhabiting the San Joaquin River. White sturgeon spawning in the San Joaquin River was documented for the first time in 2011 and confirmed in 2012. Although the majority of sturgeon likely spawn in the Sacramento River, the results of these surveys confirm that white sturgeon do spawn in the San Joaquin River in both wet- and dry-year conditions and may be an important source of production for the white sturgeon population in the Sacramento–San Joaquin River system (Section O.1.8.2.4, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

Spawning Habitat—Flow Analysis

CalSim 3 Flows

Using the Sacramento River as a surrogate, it can be inferred that the spawning period for white sturgeon in the San Joaquin River also occurs in deep water from late February to early June, peaking during March and April, (Section O.1.8.2.4, *White Sturgeon*). Because the incubation time for white sturgeon is so short, the peak impacts analysis period for incubating eggs is also considered to be March and April. Since confirmed spawning events took place in the San Joaquin River, it is reasonable to assume that rearing larvae, emigrating juveniles, and migrating adults are also present in the San Joaquin River, but due to the lack of information on these life stages they are not part of this analysis.

During the evaluated months in the spawning period, CalSim 3 estimates of mean monthly flows at Vernalis under Alternative 4 range from about 2,060 cfs for March of critically dry water years to about 12,506 cfs for April of wet water years (Table O-281). CalSim 3 results indicate that differences in flows during March and April would generally be minimal (up to 1%) under Alternative 4 compared to the No Action Alternative (Table O-281). Due to spawning occurring in deep pools, it is not anticipated that flows under Alternative 4 would have an effect on white sturgeon spawning compared to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on white sturgeon in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on spawning white sturgeon due to differences in flow. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.7.15.4 Bay-Delta

Juvenile Rearing and Emigration

White sturgeon are believed to be most abundant within the Bay-Delta region. Juveniles can be found throughout the Delta year-round. Additionally, white sturgeon larvae have been observed to be flushed farther downstream in the Delta and Suisun Bay in high outflow years, but otherwise rear higher in the system (Section O.1.9.1.6, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

<u>CalSim 3 Flows</u>

During all months, CalSim 3 estimates of mean monthly flows in the Sacramento River at Rio Vista under Alternative 4 range from about 3,222 cfs for August of critically dry water years to about 104,637 cfs for February of wet water years (Table O-274). For all water year types, CalSim 3 results indicate that differences in flows would generally be minimal (up to 5%) under Alternative 4 compared to the No Action Alternative, with a couple exceptions. Flows under Alternative 4 for above normal water years would moderately decrease in July (7%) and moderately increase April of critically dry water years (Table O-274).

CalSim 3 estimates of mean monthly total exports of SWP and CVP under Alternative 4 range from 1,538 cfs for July of critically dry water years to about 10,840 cfs for August of wet water years (Table O-271). Exports would moderately to substantially increase in February, April, and May of all water year types (up to 37%) and moderately increase in March of wet water years (13%), March and September of above normal water years (up to 22%), and October and November of critically dry water years (up to 13%). Flows would moderately decrease in December for all water year type (up to11%), June of above normal below normal, and dry water year types (up to 11%) and July and August of critically dry water years (up to 12%) (Table

O-271). It is not anticipated that changes in exports under Alternative 4 would have an effect on white sturgeon juveniles compared to the No Action Alternative.

Delta Outflow vs Sturgeon YCI

Differences in year class strength between Alternative 4 and the No Action Alternative are expected to be negligible. For additional effects of spring Delta outflow vs white sturgeon YCI under Alternative 4, refer to the analysis in Section O.7.11.3.1, *[Green Sturgeon] Larval and Juvenile Rearing and Emigration* and Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*, for additional details.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on white sturgeon year class strength due to differences in flow.

Potential Changes to Entrainment of White Sturgeon

Salvage Density

Predictions from the salvage density model for white sturgeon include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

At the CVP Jones Pumping Plant loss was similar in all water year types, whereas predicted average monthly loss of white sturgeon under Alternative 4 compared to the No Action Alternative at SWP Banks Pumping Plant was greater in wet and dry water year types and lower in below normal water year types; however, no loss is anticipated in critically dry year types at either facility (Tables O-100 and O-101). At the SWP Banks Pumping Plant predicted average monthly loss was up to 32% greater for January and May of dry water year types and as low as -9% for March, April, June, November, and December of below normal water year types (Table O-100). Historical loss of white sturgeon at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Summary

Differences in exports between Alternative 4 and the No Action Alternative are expected to have negligible impacts on the entrainment of juvenile white sturgeon at both facilities. Modeled results from the quantitative model show potential beneficial and adverse impacts, but since white sturgeon are salvaged so rarely, the numbers may not be representative.

Subadult and Adult Residency

White sturgeon are believed to be most abundant within the Bay-Delta region. Non-spawning adults can be found throughout the Delta year-round. When not undergoing spawning or ocean migrations, adults and subadults are usually most abundant in brackish portions of the Bay-Delta (Section O.1.9.1.6, *White Sturgeon*).

Potential Changes to White Sturgeon from Seasonal Operations

CalSim 3 Flows

Juveniles, subadults and non-spawning adults are in the Bay Delta year-round, refer to the CalSim 3 flow analysis in the juvenile life stage (Section O.7.15.5.1, *Juvenile Rearing and Emigration*) for changes in flow under Alternative 4 compared to the No Action Alternative.

Summary

Differences in exports between Alternative 4 and the No Action Alternative are expected to have negligible impacts on white sturgeon year class strength.

O.7.16 Native Minnows

O.7.16.1 Sacramento River

Sacramento Splittail, Hardhead, and Sacramento Hitch

- **Sacramento Splittail:** Historically, Sacramento splittail was widespread in the Sacramento River from Redding to the Delta (Rutter 1908, as cited in Moyle et al. 2004). This distribution has become somewhat reduced in recent years (Sommer et al. 1997, 2007b). During drier years there is evidence that spawning occurs farther upstream (Feyrer et al. 2005). Adult splittail migrate upstream in the lower Sacramento River to above the mouth of the Feather River and into the Sutter and Yolo Bypasses (Sommer et al. 1997; Feyrer et al. 2005; Sommer et al. 2007b). Each year, mainly during the spring spawning season, a small number of individuals have been documented at the Red Bluff Pumping Plant and the entrance to the GCID intake (Moyle et al. 2004).
- Most juvenile Sacramento splittail move from upstream areas downstream into the Delta from April through August (Meng and Moyle 1995; Sommer et al. 2007b). The production and recruitment of YOY Sacramento splittail is largely influenced by extent and duration of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Sommer et al. 1997; Moyle et al. 2004; Feyrer et al. 2006).
- **Hardhead:** Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986). They migrate upstream and into tributary streams as far as 45 miles (72.4 km) to spawning sites. Spawning behavior has not been documented, but it is assumed to be similar to that of the pikeminnow, which deposit their eggs over gravel-bottomed riffles, runs, and at the head of pools (Moyle et al. 1995). Hardhead larvae and juveniles likely inhabit stream margins with abundant cover and move into deeper habitats as they grow larger. Juvenile and adult hardhead are present in the Sacramento River year-round.
- **Sacramento Hitch:** Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta (Moyle et al. 2015). Sacramento hitch were not known to occur in high abundance in the Sacramento watershed, but they are known to prefer shallow backwater areas and historically were observed in the upper and lower Sacramento River and north Delta (Brown and May 2006; Robinson and Safran 2014).

Moyle et al. (2015) summarized habitat and distribution: Spawning takes place mainly in riffles of streams tributary to lakes, river, and sloughs after flows increase in response to spring rains, but spawning requirements are in need of further documentation. Moyle et al. (2015) indicate that YOY hitch spend the next two months after hatching shoaling in shallow water or staying close to aquatic plants before moving out into more open water at around 50-mm fork length.

Potential Changes to Sacramento Splittail, Hardhead, and Sacramento Hitch from Seasonal Operations

CalSim 3 Flows

The greatest factor in determining native minnow spawning success and recruitment is the amount and duration that crucial floodplain spawning areas are inundated during the period of native minnow migration and spawning. In wet years flows over 22,500 cfs at Tisdale, the first flood control gate, would cause the Tisdale weir to begin spilling into the Sutter Bypass (California Department of Water Resources 2010). Adult migration generally occurs during the late winter with juvenile outmigration into the Delta occurring in spring/early summer. Exact migration, spawning and outmigration timing are not well understood for native minnows, so flows were examined for the months of December through May.

CalSim 3 modeling indicates that average flow released at Keswick Dam under Alternative 4 would generally be similar to flows under No Action Alternative December through May, the range of average flows for the full simulation period are from about 6,300 cfs (April) to 11,800 cfs (February) (Table O-266). Differences in average flows at Keswick Dam under Alternative 4 are from a 2% reduction (May) to a 1% increase (December) for the full simulation period (Table O-266). Native minnows need adequate flows to allow access to upstream spawning/rearing habitat, with minimal differences in flows under Alternative 4 the effect on flow to native minnow is likely negligible as compared to the No Action Alternative.

For the full simulation period, and the months of December through May, the difference in average CalSim 3 flow estimates under Alternative 4 compared to the No Action Alternative at Wilkins Slough are minimal, with a range of 1% decrease in flows for May to a 1% increase in December (Table O-268).With little difference in average CalSim 3 flow estimates at Wilkins Slough, Alternative 4 would have a negligible effect on native minnow spawning and migration as compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 75°F observed range of suitable water temperatures for Sacramento splittail during February through May are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 307 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 84.2°F range of preferred temperatures in lab and field observations for Sacramento hitch non-spawning adults year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 308 for Keswick Dam, 309 for Red Bluff Diversion Dam, and 310 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 64°F optimal water temperature range for hardhead spawning during April through June are presented in Attachment

L.1, *Sacramento River Water Temperature Analysis*, Tables 311 for Keswick Dam and 312 for Red Bluff Diversion Dam. Full results of the analysis assessing the percent of months with water temperature outside the 57.2°F to 78.8°F commonly observed range of temperatures for non-spawning adult hardhead year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Tables 314 for Keswick Dam and 315 for Red Bluff Diversion Dam.

Results for the four analyses are summarized in Table O-102. Table O-102, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 45°F to 75°F observed range for suitable Sacramento splittail spawning, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Hamilton City (Table O-102). For the 77°F to 84.2°F preferred range for non-spawning Sacramento hitch, there were no combinations (0%) with favorable or unfavorable results at any location analyzed. For the 59°F to 64°F optimal hardhead spawning range, there were no combinations (0%) with favorable results at both locations analyzed. There were zero and one combinations (0% and 6.7%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there were zero and five combinations (0% and 8.3%, respectively) with favorable results at Keswick Dam and RBDD, respectively. There were two and one combinations (3.3% and 1.7%, respectively) with unfavorable results at Keswick Dam and RBDD, respectively. These results suggest that there would be positive and negligible negative water temperature-related effects of Alternative 4 on native minnows in the Sacramento River.

Summary

Seasonal operations impact on native minnows would likely be negligible based on the CalSim 3 analysis. Alternative 4 compared to the No Action Alternative would not impact splittail or hitch, but would have beneficial and negligibly adverse effects on non-spawning adult hardhead in the Sacramento River.

O.7.16.2 Clear Creek

Hardhead

According to Moyle et al. 2015, hardhead mainly occupy canyon reaches and deep pools in Clear Creek. Hardhead are one of the non-target species regularly caught in the RSTs in lower Clear Creek (Schraml and Chamberlain 2019a, 2019b, 2020, and 2021). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).

Potential Changes to Hardhead from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning flows in Clear Creek the CalSim 3 modeling results show that throughout the full simulation period, average flows in Clear Creek higher under Alternative 4 with the exception of a 10% reduction in February. Under Alternative 4 average flows in Clear Creek ranged from 220 cfs (April) to 301 cfs (January and February) (Table O-275). Even with a 10% reduction in February, flows would remain generally high during the period of hardhead spawning and migration so the effect of seasonal operations under Alternative 4 compared to the No Action Alternative would likely be negligible.

Hardhead are present in Clear Creek all months of the year. During the full simulation period and for all months utilizing the CalSim 3 modeling results, average flows under Alternative 4 had a range from 112 cfs (July) to 301 cfs (January and February) (Table O-275). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from 31% lower (June) to 36% higher (May) (Table O-275). With the decrease in flows in February, flows would still remain relatively high during the winter and spring, but during the fall a substantial reduction in flows would likely have a negative effect on hardhead occupying Clear Creek by limiting suitable habitat, and prey availability.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 64°F optimal water temperature range for hardhead spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Clear Creek below Whiskeytown Dam. Full results of the analysis assessing the percent of months with water temperature outside the 57.2°F to 78.8°F commonly observed range of temperatures for hardhead spawning year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 307 for Clear Creek below Whiskeytown Dam.

Results for the two analyses are summarized in Table O-103. Table O-103, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 59-64°F optimal hardhead spawning range, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results (Table O-103). For the 57.2°F to 78.8°F commonly observed range for non-spawning adult hardhead, there were no combinations (0%) with either favorable or unfavorable results below Whiskeytown Dam. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on native minnows in Clear Creek.

Summary

There are likely negligible impacts of seasonal operations on migrating and spawning adult hardhead in Clear Creek based on temperature and simulated flow analysis for Alternative 4 as compared to the No Action Alternative. However, a reduction in flows during the fall would likely have an adverse impact on juvenile and non-spawning adults occupying Clear Creek.

O.7.16.3 Lower American River

Hardhead and Sacramento Splittail

- **Hardhead:** The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are fairly common in the lower reaches of the lower American River. Hardhead are fairly common year-round in the lower reaches of the lower American River (Moyle 2002). Although migratory behavior of hardhead in the lower American River individuals is unknown, individuals from other large rivers, such as the Sacramento River, migrate into tributary streams during April and May. Hardhead typically spawn between April and May (Moyle 2002). Although hardhead early life history is largely unknown, young individuals likely remain along stream edges with dense cover and move into deeper water as they grow, which allows migrants to move back downstream in the current (Moyle 2002).

- **Sacramento Splittail:** Splittail likely spawn in the lower reaches of the lower American River (Sommer et al. 2008; Moyle et al. 2004). Because upstream migration is more directed and fish tend to swim farther upstream during wet years (Moyle 2002), more individuals are expected to use the lower American River in wet years. Although juvenile splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks of rearing on floodplain habitat (Bureau of Reclamation 2008). Most juveniles move downstream into the Delta from April to August (Meng and Moyle 1995). The primary factor potentially limiting the lower American River population of Sacramento splittail is availability of inundated floodplains for spawning and rearing habitats (Moyle et al. 2004).

Potential Changes to Hardhead and Sacramento Splittail from Seasonal Operations

<u>CalSim 3 Flows</u>

During the December through May period for adult migration and spawning for flows in the lower American River below Nimbus Dam the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 4 average flows in the lower American River at Nimbus ranged from 3,567 cfs (April) to 6,461 cfs (February) (Table O-277). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 2% reduction (March) to a 2% increase (January and February) (Table O-277). With minimal differences in flows native minnow migration and spawning would likely have a negligible affect under Alternative 4 compared to the No Action Alternative.

During the full simulation period, and all months, CalSim 3 estimates of mean monthly flows below Nimbus Dam under Alternative 4 are from 1,417 cfs (October) to 6,355 cfs (February) (Table O-277). The difference in average flows under Alternative 4 as compared to the No Action Alternative for the full simulation period range from a 6% reduction (September and October) to a 3% increase (November) (Table O-277). With minimal differences in flows native minnows occupying the lower American River would likely have a negligible affect under Alternative 4 compared to the No Action Alternative.

During the December through May period for adult migration and spawning for flows in the lower American River at H street the CalSim 3 modeling results show that throughout the full simulation period differences in average flows are minimal. Under Alternative 4 average flows in the lower American River at H street ranged from 3,488 cfs (April) to 6,351 cfs (February) for the period of December through May (Table O-278). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 2% reduction (March) to a 2% increase (January and February) (Table O-278). With minimal differences in flows native minnow migration and spawning would likely have a negligible affect under Alternative 4 compared to the No Action Alternative.

During all months, and for the full simulation period, CalSim 3 estimates of mean monthly flows at H Street under Alternative 4 range from 1,312 (October) to 6,351 cfs (February) (Table O-278). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 7% reduction (September) to a 3% increase (November) for the full simulation period (Table O-278). With minimal differences in flows native minnows occupying the lower American River would likely have a negligible affect under Alternative 4 compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 45°F to 75°F water temperature range observed for Sacramento splittail suitable spawning during February through May are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 87 for Hazel Avenue and Table 88 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the outside the 59°F to 64°F water temperature optimal range for hardhead spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 89 for Hazel Avenue and Table 90 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the outside the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 91 for Hazel Avenue and Table 92 for Watt Avenue.

Results for these three analyses are summarized in Table O-104. Table O-104, as described in Section O.4.16.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 45°F to 75°F temperature range observed for suitable spawning for Sacramento splittail under Alternative 4, there were zero month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-104). There were also zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 59°F to 64°F water temperature optimal range for hardhead spawning under Alternative 4, there were one and two month-water year type combinations (6.7% and 13.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There was one month-water year type combinations (6.7%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were three and two month-water year type combinations (5.0% and 3.3%, respectively) with favorable results at both Hazel Avenue and Watt Avenue. There were one and

two month-water year type combinations (1.7% to 3.3%, respectively) with unfavorable results at both Hazel Avenue and Watt Avenue.

Overall, these results suggest that there would be positive and negative water temperatures-related effects of Alternative 4 on native minnows in the lower American River.

Summary

There are likely negligible impacts of seasonal operations on native minnow in the lower American River based on the difference in simulated flows for Alternative 4 compared to the No Action Alternative. However, the temperature analysis for the lower American River at Hazel and Watt Avenue shows that beneficial and adverse temperature related impacts are expected for hardhead spawning and non-spawning adults under Alternative 4. Water temperature related impacts on Sacramento splittail are likely negligible in the lower American River at Watt Ave and Hazel Ave. With negligible flow related impacts, and beneficial and adverse temperature related impacts, overall Alternative 4 would have a beneficial and adverse impact on native minnows in the lower American River as compared to the No Action Alternative.

O.7.16.4 Stanislaus River

Hardhead

The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are a frequent catch in the lower Stanislaus River (Bradbury and Hickey 2019). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).

Potential Changes to Hardhead from Seasonal Operations

CalSim 3 Flows

During the December through May period for adult migration and spawning for flows in the Stanislaus River at the confluence with the San Joaquin the CalSim 3 modeling results show that throughout the full simulation period average flows are similar for Alternative 4 compared to the No Action Alternative. Under Alternative 4 average flows in the Stanislaus River at the confluence ranged from 532 cfs (December) to 1,161 cfs (May) (Table O-280). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 3% reduction (May) to a 4% increase (December) for the full simulation period and months of December through May (Table O-280). With minimal differences in flows hardhead migration and spawning would likely have a negligible affect under Alternative 4 compared to the No Action Alternative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the Stanislaus River at the confluence of the San Joaquin under Alternative 4 range from 346 cfs (July) to 1,161 cfs (May) (Table O-280). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 3% reduction (May) to a 7% increase (August) for the full simulation period and all months (Table O-280). Hardhead are present in the Stanislaus River all months of the year. With minimal differences in flows hardhead occupying the Stanislaus River would likely have a negligible affect under Alternative 4 compared to the No Action Alternative.

During the December through May period for adult migration and spawning for average flows in the Stanislaus River below Goodwin Dam the CalSim 3 modeling results show that throughout the full simulation period flows will be generally similar for Alternative 4 compared to the No Action Alternative. Under Alternative 4 average flows in the Stanislaus River below Goodwin Dam ranged from 527 cfs (December) to 1,048 cfs (February) for the months December through May (Table O-279). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 8% reduction (April) to a 7% increase (February) (Table O-279). Somewhat substantial decreases in flows during the crucial month of April, most notably in dry and below normal water year types may have a negative effect on hardhead spawning. Overall, flows are similar under Alternative 4 compared to the No Action Alternative, so the effect on hardhead spawning and migration would likely be negligible or slightly negative.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the Stanislaus River below Goodwin Dam under Alternative 4 had a range from 295 cfs (July) to 1,048 cfs (February) (Table O-279).The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 8% reduction (April) to a 10% increase (August) for the full simulation period, and all months (Table O-279). Hardhead are present in the Stanislaus River for all months of the year. Somewhat substantial decreases in flows during the crucial month of April, most notably in dry and below normal water year types may have a negative effect on hardhead spawning. Overall, flows are similar under Alternative 4 compared to the No Action Alternative, so the effect on hardhead occupying the Stanislaus River would likely be negligible.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the outside the 59°F to 64°F water temperature optimal range for hardhead spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 868 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the outside the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 69 for Orange Blossom Bridge.

Results for these two analyses are summarized in Table O-105. Table O-105, as described in Section O.4.16.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 59°F to 64°F water temperature optimal range for hardhead spawning under Alternative 4, there was one month-water year type combination (6.7%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-105). For the 57.2°F to 78.8°F observed water temperature range for non-spawning adult hardhead, there were two month-water year type combinations (3.3%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge.

These results suggest that Alternative 4 would have negligible water temperature-related effects on native minnows in the Stanislaus River at Orange Blossom Bridge.

Summary

Utilizing the CalSim 3 flow analysis, Alternative 4 would have a negligible impact on hardhead in the Stanislaus River except for a few instances. Most notably, in dry water year types reduced flows in the Stanislaus River below Goodwin would have an adverse impact on hardhead under Alternative 4. However, based off the temperature analysis for the Stanislaus River the impact of temperature under Alternative 4 would be negligible. Given that the impact of temperature under Alternative 4 is negligible, but flow related impacts are just slightly negative, overall hardhead would likely have a negligible to a slightly adverse impact as compared to the No Action Alternative.

O.7.16.5 San Joaquin River

Sacramento Splittail, Hardhead, and Sacramento Hitch

- **Sacramento Splittail:** Historically, Sacramento splittail were widespread in the San Joaquin River and found upstream to Tulare and Buena Vista lakes, where they were harvested by native peoples (Moyle et al. 2004). Today, Sacramento splittail likely ascend the San Joaquin River to Salt Slough during wet years (Baxter 1999). During dry years, Sacramento splittail are uncommon in the San Joaquin River downstream of the Tuolumne River (Moyle et al. 2004).

  The population of Sacramento splittail is largely influenced by extent and period of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Moyle et al. 2004).

- **Hardhead:** In the San Joaquin drainage, hardhead are present throughout tributary streams but are largely absent from the valley reaches of the San Joaquin River (Moyle et al. 2015, Moyle and Nichols 1973, Saiki 1984). Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang 1986).

- **Sacramento Hitch:** Sacramento hitch historically occurred in low-elevation streams throughout the Sacramento and San Joaquin Valleys and in the Delta, but are now absent from the San Joaquin River and tributaries between Friant Dam and the Merced River (Moyle et al. 2015). Sacramento hitch are occasionally captured in low numbers in the lower San Joaquin River in the Mossdale trawl monitoring program (Interagency Ecological Program et al. 2022).

Potential Changes to Sacramento Splittail, Sacramento Hitch, and Hardhead from Seasonal Operations

During the December through May period for adult migration and spawning for average flows in the San Joaquin at Vernalis the CalSim 3 modeling results show that throughout the full simulation period flows are similar under Alternative 4 compared to the No Action Alternative. Under Alternative 4 average flows in the San Joaquin at Vernalis ranged from 2,890 cfs (December) to 6,451 cfs (February) (Table O-281). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 1% reduction (May) to a 1% increase (December) for the full simulation period and for months December through May

(Table O-281). Overall, flows are similar under Alternative 4 compared to the No Action Alternative, so the effect on native minnow spawning and migration would likely be negligible.

During all months, and for the full simulation period CalSim 3 estimates of mean monthly flows for the San Joaquin at Vernalis under Alternative 4 range from 1,434 cfs (August) to 6,451 cfs (February) (Table O-281). The difference in average flows under Alternative 4 compared to the No Action Alternative had a range from a 1% reduction (May) to a 3% increase (August) for the full simulation period, and all months (Table O-281). Presence of native minnows in the San Joaquin are not well known, but it is likely that many species are present year-round. Overall, flows are similar under Alternative 4 compared to the No Action Alternative, so the effect on native minnow occupying the San Joaquin River would likely be negligible.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on native minnows in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Based off the CalSim 3 flow analysis flows under Alternative 4, differences in predicted flows are minimal. Given that differences in predicted CalSim 3 flows are minor, the impact of seasonal operations for Alternative 4 as compared to the No Action Alternative would likely be negligible. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.7.16.6 Bay-Delta

Hardhead, Sacramento Hitch, and Sacramento Splittail

- **Hardhead:** The extant range of hardhead includes the Sacramento–San Joaquin River Basin, and are present in low abundance in the San Francisco Estuary and Delta. Brown and Michniuk (2007) electrofished parts of the Bay-Delta in the 1980's and 2000's and captured small numbers of hardhead. Retrieval of hardhead at the SWP/CVP south Delta fish salvage facilities remain relatively low (California Department of Water Resources 2020:4-62).
- **Sacramento Hitch:** The species is distributed in the Sacramento River Basin, in low numbers in the San Joaquin River Basin, and occasionally captured during monitoring programs in the Delta (Moyle et al. 2015; Interagency Ecological Program et al. 2022). Monitoring data suggests year round presence in the Delta (Interagency Ecological Program et al. 2022).
- **Sacramento Splittail:** Adult Sacramento splittail typically migrate upstream from brackish areas in January and February and spawn in freshwater, particularly on inundated floodplains when they are available, in March and April (Sommer et al. 1997; Moyle et al. 2004; Sommer et al. 2008). A substantial amount of splittail spawning occurs in the Yolo and Sutter Bypasses and the Cosumnes River area of the Delta (Moyle et al. 2004).

Although juvenile Sacramento splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks or months of rearing in floodplain habitats along the rivers (Feyrer et al. 2006). Juveniles move downstream into the Delta from April to August (Meng and Moyle 1995; Feyrer et al. 2005). Sacramento splittail recruitment is largely limited by extent and period of inundation of floodplain spawning habitats, with abundance observed to spike following wet years and dip after dry years (Moyle et al. 2004).

Potential Changes to Sacramento Splittail, Sacramento Hitch, and Hardhead from Seasonal Operations

CalSim 3 Flows

For many species of native minnow, it has been shown that changes in export flows can lead to higher levels of entrainment which can potentially influence population dynamics. Certain species such as Sacramento splittail are known to utilize the Delta for many portions of their life history so flows into the Delta will have a strong effect on these fish by limiting habitat, prey availability and access to spawning areas. Since many native minnows occupy the Delta year-round, flows and exports were examined for all months of the year.

During all months and for the full simulation period, CalSim 3 estimates of average Delta outflow would be similar under Alternative 4 compared to the No Action Alternative. CalSim 3 estimates of average Delta outflow for all months have a range from 3,870 cfs (August) to 58,501 cfs (February) for Alternative 4 and for the full simulation period (Table O-272). Differences in average outflow under Alternative 4 as compared to the No Action Alternative would be from a 6% reduction (May) to a 6% increase (December) for the full simulation period and all months (Table O-272). Overall, flows are similar under Alternative 4 compared to the No Action Alternative, so the effect on native minnows in the Delta would be likely be negligible.

CalSim 3 estimates of mean monthly average flow for the total exports of SWP and CVP under Alternative 4 for the full simulation period, and all months, range from 5,171 cfs (April) to 8,215 cfs (February) (Table O-271). The range of average export flow difference under Alternative 4 compared to the No Action Alternative for the full simulation period, and all months, were from a 12% reduction in exports (December) to a 25% increase in exports (May) (Table O-271). Overall, average export flows are similar for Alternative 4 compared to the No Action Alternative, but substantial increases in exports would occur during a crucial period for native minnows spawning and migration. With increased average export flows for the months of April/May and for all water year types, entrainment would likely increase under Alternative 4, having a negative effect on native minnow populations as compared to the No Action Alternative.

Summary

Utilizing the CalSim 3 predicted flow analysis, Alternative 4 would have similar predicted Delta outflow as compared to the No Action Alternative. Since differences in Delta outflow are minor, the impact of outflow on native minnows would likely be negligible. However, while average export flows are similar for Alternative 4 compared to the No Action Alternative, substantial increases in exports would occur during a crucial period for native minnows spawning and migration. With increased average export flows for the months of April/May and for all water

year types, entrainment would likely increase under Alternative 4, having an adverse impact on native minnows when compared to the No Action Alternative.

Potential Changes to Entrainment of Sacramento Splittail, Sacramento Hitch, and Hardhead

Sacramento Splittail: Salvage Density

Predictions from the salvage density model for Sacramento splittail include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of Sacramento splittail at SWP Banks Pumping Plant for all months of the year and all water year types Alternative 4 was greater than predicted average monthly loss under the No Action Alternative for all but below normal water year types, with up to 62% higher for above normal water year types and 1% lower for below normal water year types (Table O-106). Predicted average monthly loss of Sacramento splittail at CVP Jones Pumping Plant for all months of the year and all water year types Alternative 4 was higher than predicted average monthly loss under the No Action Alternative for all water year types except for dry water year types. For all water year types Alternative 4 as compared to the No Action Alternative at Jones had a range from up to 3% higher for below normal water year types to 11% lower for dry water year types, it should also be noted that in critically dry water year types predicted loss only occurred for 6 months of the year (Table O-107). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Sacramento Hitch: Salvage Density

Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of Sacramento hitch at SWP Banks Pumping Plant for all months of the year and all water year types, Alternative 4 was higher than predicted average monthly loss under the No Action Alternative for all water year types except for dry water year types, there was no predicted loss for critically dry water year types. Predicted average monthly loss at Banks under Alternative 4 had a range from 4% lower for dry water year types to 177% higher for above normal water year types (Tables O-110). Predicted average monthly loss of Sacramento hitch at CVP Jones Pumping Plant for the months of March through April and all water year types Alternative 4 was equal or higher than predicted average monthly loss under the No Action Alternative. The range of predicted loss for Sacramento hitch at Jones under Alternative 4 compared to the No Action Alternative was from 0% in above normal water year types to 12% higher for wet water year types, no fish were predicted to be lost in dry and critically dry water year types. It should be noted that loss of Sacramento hitch at both facilities is rare and infrequent, with such low values of predicted loss, the percent differences may not be representative. (Table O-111). For detailed information on average monthly loss by water year type, see Attachment I.2, *Salvage Density Model Loss Simulation*.

Hardhead: Salvage Density

Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Whereas at the CVP Jones Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of hardhead of Alternative 4 compared to the No Action Alternative at SWP Banks Pumping Plant was greater all water year types, except in below normal and dry water year types when no fish are expected (Tables O-108 and O-109). At the SWP Banks Pumping Plant predicted average monthly loss was between 8% and 177% greater in September of critically dry water years and April of above normal water year, respectively (Table O-108). Historical loss of hardhead at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Summary

With higher exports for most months and water year types, higher levels of entrainment are predicted. While there are a few instances where predicted loss would be lower, most water year types and months have higher predicted loss for native minnows at both facilities for Alternative 4 as compared to the No Action Alternative.

O.7.17 Pacific Lamprey

O.7.17.1 Trinity River

Spawning and Egg Incubation

Pacific lamprey typically spawn from March through June, when daily mean water temperatures range from 50–64°F, with peak spawning occurring typically occurring in April and May and when water temperatures are approximately 57–59°F (Stone 2006, Brumo et al. 2009). Redds are typically constructed in gravel and cobble substrates within pool and run tailouts and low gradient riffles (Stone 2006, Brumo et al. 2009). Eggs are deposited in the redd and hatch after approximately 15 days, depending on water temperatures (Meeuwig et al. 2005, Brumo 2006). Egg-sac larvae spend another 15 days in redds before emergence. Water temperatures in excess of 65°F during incubation have been shown to reduce embryo survival (Meeuwig et al. 2005). The effects analysis period for spawning and egg incubation in the Trinity River is March through July.

Potential Changes to Pacific Lamprey from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 4 to flows under the No Action Alternative during spawning and egg incubation periods for Pacific lamprey. Differences in monthly average flows between Alternative 4 and the No Action Alternative greater than 5% in reduction of flows would occur in March of wet years (Table O-264). Under Alternative 4 compared to the No Action Alternative, flow decreases would occur during the Pacific lamprey spawning and egg incubation period. The reduction in flows in wet years would likely be negligible for spawning habitat and egg incubation as flows would remain above 1,881 cfs.

The flow decreases in March in below wet water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative. Modeled monthly average water temperatures under Alternative 4 would remain well below the upper water

temperature suggested for Pacific lamprey spawning and egg incubation of 65°F in the reach from Lewiston Dam to the North Fork Trinity River (Asarian et al. 2023).

Ammocoete Rearing and Emigration

After emergence from redds, eyeless Pacific lamprey larvae, known as ammocoetes, settle out of the water column and burrow into fine silt and sand substrates, often containing organic matter. Ammocoetes rear in these habitats for 4–10 years. Water temperature requirements for the life stage are not well described. Ammocoetes have been observed burrowed in substrates in streams with water temperatures up to 80°F (Claire 2004), and upper temperature tolerances are estimated to be around 83°F (Whitesel and Uh 2022). After Pacific lamprey metamorphose to the macropthalmia stage, individuals migrate to the ocean typically in conjunction with high flow events between fall and spring, but can occur year-round. The effects analysis period for ammocoete rearing is year-round and emigration is primarily fall through spring in the Trinity River

Potential Changes to Pacific Lamprey from Seasonal Operations

Under Alternative 4, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (Table O-264). The reduction in flows could have minor adverse impacts in the reduction of rearing habitat, and reduced flows during peak emigration periods in December of below normal years as flows decrease from 931 to 816 cfs. Alternative 4 monthly average flows will have negligible to minor adverse impacts on ammocoete rearing and emigration of Pacific lamprey when compared to the No Action Alternative.

The flow decreases in February and March of wet water years, November of above normal water years, and December of below normal water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam but there would be no substantial differences relative to the No Action Alternative. Modeled monthly average water temperatures under Alternative 4 would remain well below the upper water temperature threshold for Pacific lamprey ammocoete and emigration of 83°F in the reach from Lewiston Dam to the North Fork Trinity River (Asarian et al. 2023).

Adult Upstream Migration and Holding

Adult Pacific lamprey typically enter freshwater from winter to early summer, but in the Klamath River adults have been reported to enter year-round (Petersen Lewis 2009, Parker 2018). In general, adult Pacific lampreys have two life history types: ocean maturing where individuals likely spawn several weeks after entering freshwater, and stream maturing where individuals spend one year in freshwater prior to spawning (Clemens et al. 2013, Parker et al. 2019). In general, adult Pacific lamprey hold in interstitial spaces within large cobble and boulders and also in glides, runs, and riffles (Lampman 2011). Water temperature requirements for holding adult Pacific lampreys have not been fully evaluated, but adults have been observed in temperatures ranging from 60 to 84°F (Starcevich et al. 2014). The effects analysis period for adult upstream migration and holding in the Trinity River is year-round.

Potential Changes to Pacific Lamprey from Seasonal Operations

Under Alternative 4, monthly average flows would be similar or have greater than 5% reduction in flows compared to the No Action Alternative during February and March in wet years, November in above normal years, and December in below normal years (Table O-264). The reduction in flows in winter would likely have minor adverse impacts on the adult upstream migration as flows would remain above 1,726 cfs in wet years in February and March, and 816 cfs in below normal years in December. Alternative 4 monthly average flows will have minor adverse to negligible impacts on adult upstream migration and holding of Pacific lamprey when compared to the No Action Alternative.

The flow decreases in February and March of wet water years, November of above normal water years, and December of below normal water years may result in negligible changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam. Modeled monthly average water temperatures under Alternative 4 would remain well below the upper water temperature threshold for Pacific lamprey adult upstream migration and holding of 84°F in the reach from Lewiston Dam to the North Fork Trinity River (Asarian et al. 2023).

O.7.17.2 Sacramento River

Spawning and Egg Incubation

Pacific lamprey construct redds in shallow water (about 0.5 to 3.5 feet or 0.15 to 1 meter) gravel habitats in the upper river and spawning occurs from March through July with peak spawning typically occurring in early April (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015). The eggs and pro-larvae incubate for about 30 to 45 days. Water flows and temperature impacts on eggs are March-August but are largely April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

<u>CalSim 3 Flows</u>

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam are largely similar to those under the No Action Alternative (Table O-266 and Table O-267). Impacts on Pacific lamprey spawning and egg incubation are expected to be minimal. Flows are almost unchanged at both locations from those under the No Action Alternative. The greatest changes in the spawning period are several flow decreases in critically dry years. However, flows are expected to remain high enough that redds should not face dewatering, and spawning and egg incubation will likely not see any serious adverse impacts. Most of these critically dry decreases come in months with more robust flows, compared to others that have weaker flow but see little change. While minor adverse impacts are possible in critically dry years, survival should not be affected and overall impacts across water-year types are expected to be minimal.

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey during April through August are presented in Attachment L.1,

Sacramento River Water Temperature Analysis, Table 295 for Keswick Dam and Table 296 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-112. Table O-112, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were zero and one month-water year type combinations (0% and 4.0% of total combinations during the period, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-112). There were no combinations (0%) with unfavorable results at both Keswick Dam and RBDD. These results suggest that there would be negligible water temperature-related impacts of Alternative 4 on Pacific lamprey spawning and egg incubation in the Sacramento River.

Summary

Alternative 4 is expected to have minor adverse impacts on Pacific lamprey spawning and egg incubation relative to the No Action Alternative. Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey spawning and egg incubation in the Sacramento River.

Ammocoete Rearing and Emigration

After Pacific lamprey larvae (ammocoetes) emerge, they drift downstream and burrow into fine sediments to rear. Ammocoetes select habitats that are often off-channel, with low flow velocity and shallow depths; therefore, they are vulnerable to stranding by reductions in water level. After three or more years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean. Data from rotary screw trapping at sites on the mainstem Sacramento River indicate that emigration of Pacific lamprey peaks from early winter through early summer, but some emigration is observed year-round at both the RBDD and the GCID diversion dam (Hanni et al. 2006).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Redd Bluff Diversion Dam and below Keswick Dam are mostly similar to those under the No Action Alternative (Table O-266 and Table O-267). Impacts on Pacific lamprey ammocoete rearing and emigration are likely to be minimal. Ammocoete rearing could see some minor adverse impacts in critically dry years, as flows decrease in some spring and summer months, but flow values are expected to remain high enough that survival should not be threatened. Increases in some fall and winter months could have slight beneficial impacts. Overall, ammocoete rearing would likely see some minimal beneficial and adverse impacts compared to the No Action Alternative. Juvenile emigration is likely to also see minimal impacts from flow changes under Alternative 4. Some slight flow increases in fall and winter months could have minimal beneficial impacts during the emigration period, but flows are largely similar to those under the No Action Alternative, and overall impacts are expected to be minimal.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific Lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 298 for Keswick Dam and Table 299 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-113. Table O-113, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results at both Keswick Dam and RBDD (Table O-113). These results suggest that there would be negligible water temperature-related impacts of Alternative 4 on Pacific lamprey ammocoete rearing and emigration in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration in the Sacramento River due to differences in water temperatures.

O.7.17.3 Clear Creek

Spawning and Egg Incubation

Pacific lamprey usually spawn in Clear Creek from March through July, depending on water temperatures and local conditions such as seasonal flow regimes. The adults construct redds similar to steelhead redds, and eggs incubate for 11 to 30 days, depending on the water temperature, prior to hatching. Although the extent of spawning is unknown, the species spawns in Clear Creek as evidenced by ammocoetes routinely collected in the screw trap at RM 1.7. Effects from water flows and temperature on eggs are likely felt March-August, and they likely peak in accordance with peak spawning April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in Clear Creek below Whiskeytown Dam under Alternative 4 would see a mix of increases and decreases compared to the No Action Alternative depending on month and water year type (Table O-275). Impacts of these flow changes on Pacific lamprey spawning would likely be mixed, with beneficial impacts from flow increases during the peak spawning period in March, April and May, and adverse impacts from flow decreases at the beginning and end of the spawning period during some or all water year types for February and June through August.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities for Pacific lamprey during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 288 for Clear Creek below Whiskeytown Dam.

Results for the analysis are summarized in Table O-114. Table O-114, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 50°F to 64°F observed range of high survival and low occurrence of embryonic developmental abnormalities, there were five month-water year type combinations (20.8% of total combinations during the period) with favorable results and no combinations (0%) with unfavorable results below Whiskeytown Dam (Table O-114). These results suggest that there would be positive water temperature-related impacts of Alternative 4 on Pacific lamprey spawning and egg incubation in Clear Creek.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial to adverse impacts on Pacific lamprey spawning and egg incubation due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have beneficial impacts on Pacific lamprey spawning and egg incubation in Clear Creek due to differences in water temperatures.

Ammocoete Rearing and Emigration

Pacific lamprey rearing takes place over a matter of years. Hatched embryos remain in the gravel for up to one more month as gill slits develop. The ammocoetes then spend three to seven years in soft sediments as filter feeders (USFWS 2019). Once ammocoetes have become juveniles, they begin to migrate towards the ocean in spring and possibly early summer. Effects from water temperature and flow on larval and juveniles are year-round due to their prolonged rearing in their home waters, with spring and summer flows during migratory periods being important as well.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in Clear Creek below Whiskeytown Dam under Alternative 4 would see a mix of increases and decreases compared to the No Action Alternative (Table O-275). Impacts on Pacific lamprey ammocoete rearing would likely be mixed, as rearing takes place over several years, and positive impacts during months and water years with increased flows would likely be balanced by negative impacts from those months and water year types with decreased flows. Juvenile emigration for Pacific lamprey would likely see some beneficial impacts under Alternative 4, as flows generally increase during the peak outmigration period in winter and spring months, with the exception of February, which sees flow decreases in wet, above normal, and below normal years.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific Lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 291 for Clear Creek below Whiskeytown Dam.

Results for the analysis are summarized in Table O-115. Table O-115, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results below Whiskeytown Dam (Table O-115). These results suggest that there would be negligible water temperature-related impacts of Alternative 4 on Pacific lamprey ammocoete rearing and emigration in Clear Creek.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial to adverse impacts on Pacific lamprey ammocoete rearing, and beneficial impacts on Pacific lamprey juvenile emigration. Differences in Alternative 4 is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration in Clear Creek due to differences in water temperatures.

O.7.17.4 Lower American River

Spawning and Egg Incubation

Hannon and Deason (2008) documented Pacific lamprey spawning in the lower American River from early January to late May, with peak spawning typically occurring in early April. Redds are built in shallow water environments and eggs incubate for several weeks before larvae emerge. Water temperature and flow impacts on eggs are likely January-June, with peak impacts April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the lower American River at H Street and below Nimbus Dam under Alternative 4 would see a mix of small increases and decreases compared to the No Action Alternative (Table O-277 and Table O-278). Impacts on Pacific lamprey spawning would likely be relatively minor, as few months see large changes (up to 14% increase below Nimbus) in flow compared to the No Action Alternative. The largest impacts would likely be during the middle of the spawning period in critically dry years, with March and April having the some of the largest relative decreases and would likely see the greatest adverse impacts. Generally, however, flow changes are fairly small in scope and are a mix of increases and decreases, so

overall impacts on spawning from changes due to Alternative 4 would likely be mixed beneficial and adverse depending on month and water year type, but largely minimal.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities during March through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 79 for Hazel Avenue and Table 80 for Watt Avenue.

Results for the analysis are summarized in Table O-116. Table O-116, as described in Section O.4.17.4.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities for Pacific lamprey spawning and egg incubation under Alternative 4, there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at both Hazel Avenue and Watt Avenue (Table O-116). There were three and one month-water year type combinations (12.0% and 4.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that Alternative 4 would have positive (4% favorable) and negative (4% to 12% unfavorable) water temperature-related impacts to Pacific lamprey spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial to adverse impacts on Pacific lamprey spawning and egg incubation in the lower American River due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have beneficial and adverse impacts on Pacific lamprey spawning and egg incubation in the lower American River due to differences in water temperatures.

Ammocoete Rearing and Emigration

Pacific lamprey ammocoetes rear in the lower American River for all or part of their 3- to 7-year freshwater residence. Larvae spend a month maturing to ammocoetes before leaving spawning areas to find suitable rearing habitat, usually shallow, off-channel areas with low flow velocity where they will spend the next several years filter-feeding and maturing to juvenile stage. Once juveniles, they will begin migrating towards the ocean. Data from rotary screw trapping in the nearby Feather River suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006), although some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006) and in other river systems (Moyle 2002).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the lower American River at H Street and below Nimbus Dam under Alternative 4 would see a mix of increases and decreases compared to the No Action Alternative (Table O-277 and Table O-278). Impacts on Pacific lamprey ammocoete rearing are likely to be mixed as well, but overall minimal. As rearing takes place over a period of several years, ammocoetes are subject to the range of flow increases and decreases, but as they are predicted to largely be small in scope, rearing would likely not see many beneficial or adverse impacts. Decreased flows in some months of critically dry water years (up to 23% below Nimbus) could have an adverse impact on ammocoete rearing, especially since ammocoetes spend this period buried in off-channel pools that could be at risk of drying out in critically dry years, but the risk of this is difficult to assess. Impacts on Pacific lamprey juvenile emigration are likely to be mixed as well, depending on water year type, but are likely to be similarly minimal due to the small increases and decreases that characterize the months in the winter-early summer emigration window.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 48 for Hazel Avenue and Table 50 for Watt Avenue.

Results for the analysis are summarized in Table O-117. Table O-117, as described in Section O.4.17.4.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific lamprey ammocoete rearing and emigration under Alternative 4, there were zero and two month-water year type combinations (0.0% and 3.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-117). There were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 4, there would be positive (3.3% favorable) and negative (1.7% unfavorable) water temperature-related impacts to Pacific lamprey ammocoete rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial to adverse impacts on Pacific lamprey ammocoete rearing and emigration due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have positive and negative impacts on Pacific lamprey ammocoete rearing and emigration in the lower American River due to differences in water temperatures.

O.7.17.5 Stanislaus River

Spawning and Egg Incubation

Hannon and Deason (2008) have documented Pacific lampreys spawning in the lower American River from early January to late May, with peak spawning typically in early April. Spawning time is presumably similar in the Stanislaus River. Eggs are laid in redds constructed in shallow water, and incubation takes several weeks. Effects from water flows and temperature on eggs are present February-June, likely with a peak April-May.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Stanislaus River at the mouth and below Goodwin Dam under Alternative 4 will see a mix of increases and decreases relative to the No Action Alternative depending on month and water year type (Table O-279 and Table O-280). Impacts on Pacific lamprey spawning at the mouth would likely be minimal, as the relative flow changes are predicted to be fairly small, and the flow increases and decreases over the spawning period relative to the No Action Alternative impact. Below Goodwin Dam, impacts on Pacific lamprey spawning would likely be slightly adverse, as flows generally decrease during the peak spawning period of April and May, with some flows decreasing in March and June.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities during April through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 62 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-118. Table O-118, as described in Section O.4.17.5, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 with TUCP without VA for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities of Pacific lamprey, there were no month-water year type combinations (0.0%) with favorable or unfavorable results at both Orange Blossom Bridge and above the confluence of the San Joaquin River (Table O-118).

These results suggest that Alternative 4 would have negligible water temperature related impacts on Pacific lamprey spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

Alternative 4 relative to the No Action Alternative is expected to have minor adverse impacts on Pacific lamprey spawning and egg incubation due to flow differences. Alternative 4 relative to the No Action Alternative is expected to have negligible water temperature-related impacts on Pacific lamprey spawning and egg incubation in the Stanislaus River.

Ammocoete Rearing and Emigration

Pacific lamprey ammocoetes are expected to rear in the Stanislaus River for all or part of their three- to seven-year freshwater residence. Larvae usually spend a month in their spawning areas before becoming ammocoetes and moving to rearing habitat in shallow, off-channel areas. After several years, they become juveniles and migrate out to the ocean. Data from rotary screw trapping in the nearby Mokelumne and Tuolumne Rivers suggest that out-migration of Pacific lamprey generally occurs from early winter through early summer (Hanni et al. 2006). Catches of juvenile Pacific lampreys in trawl surveys of the mainstem San Joaquin River, near the mouth of the Stanislaus River at Mossdale, occurred during winter and spring. Some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Stanislaus River at the mouth and below Goodwin Dam under Alternative 4 will see a mix of increases and decreases relative to the No Action Alternative depending on month and water year type (Table O-279 and Table O-280). Impacts on Pacific lamprey ammocoete rearing are likely to be mixed, with flow increases and decreases with their accompanying impacts but are likely adequate for this life stage. Impacts on juvenile emigration are similarly likely to be mixed. Flow increases in some winter months during the early part of the outmigration period; flows then see some decreases in spring months during the later part of the emigration period.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 63 for Orange Blossom Bridge and Table 64 for the Stanislaus River above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-119. Table O-119, as described in Section O.4.17.5, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Pacific lamprey, there were no month-water year type combinations (0.0%) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-119). There were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 4 would have negligible water temperature related impacts on Pacific lamprey ammocoete rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial to adverse impacts on Pacific lamprey ammocoete rearing and emigration due to flow differences. Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on Pacific lamprey ammocoete rearing and emigration in the Stanislaus River due to water temperature differences.

O.7.17.6 San Joaquin River

Ammocoete Rearing and Emigration

Pacific lamprey larvae, once emerged, spend roughly a month in spawning areas before becoming ammocoetes and moving to rearing habitat in shallow, off-channel waters with low flow velocity, where they will spend the following several years (roughly three to seven) maturing to the juvenile stage. Once juveniles, they begin a migration towards the ocean. Midwater trawl surveys in the San Joaquin River suggest that peak ammocoete out-migration occurs in January and February (Hanni et al. 2006). Ammocoetes are vulnerable to habitat loss due to the nature of their rearing habitat.

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 models predict that flows in the San Joaquin River at Vernalis under Alternative 4 will see a mix of increases and decreases relative to the No Action Alternative. Impacts from changes in flow on ammocoete rearing would likely be minimal (Table O-281). Slightly increased flows in summer months of critically dry water years would likely have some small beneficial impacts on the success of ammocoete rearing, though the extent of these impacts is difficult to determine. Flow changes under Alternative 4 compared to the No Action Alternative would likely have minimal impact on juvenile emigration, as flows see little change during the winter and spring months when outmigration is at its peak.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on Pacific lamprey in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 4 relative to the No Action Alternative are expected to have beneficial impacts on Pacific lamprey ammocoete rearing and emigration in the San Joaquin River due to differences in flow. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.7.17.7 Bay-Delta

Some Pacific lamprey ammocoetes likely spend part of their extended (3 to 7 years) freshwater residence rearing in the Delta, particularly in the upstream, freshwater portions (California Department of Water Resources et al. 2013). Ammocoetes are present year-round in all of the regions (California Department of Water Resources et al. 2013). Data from the Fall Midwater Trawl Survey in the lower Sacramento and San Joaquin Rivers and Suisun Bay suggest that peak out-migration of Pacific lamprey through the Delta coincides with high-flow events from fall

through spring (Hanni et al. 2006).Water temperature and flows affect resident ammocoetes year round and migrating juveniles fall-spring. Duration of estuarine adult migration and holding in the San Francisco Estuary is poorly understood, but some evidence suggests they may migrate as early as the fall and throughout the spawning season until late June (Moyle et al. 2015).

Potential Changes to Pacific Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Sacramento River at Rio Vista under Alternative 4 would see a mix of increases and decreases compared to the No Action Alternative (Table O-274). For impacts in the southern Delta, see the San Joaquin River section above, which discusses flow at Vernalis. Under Alternative 4, flows at Rio Vista would see a mix of increases and decreases but would be relatively unchanged compared to the No Action Alternative. Impacts on Pacific lamprey ammocoete rearing would likely be negligible, as flows are likely adequate for rearing. Impacts on juvenile emigration and adult migration would be beneficial in April of critically dry water year types.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial impacts on Pacific lamprey juvenile emigration and adult migration in April of critically dry water year types due to differences in flow. Impacts on ammocoete rearing are expected to be negligible.

Potential Changes to Entrainment of Pacific Lamprey

Salvage Density

Predictions from the salvage density model for Pacific lamprey include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for the alternatives, predicted average monthly loss of Pacific lamprey of Alternative 4 compared to the No Action Alternative at CVP Jones Pumping Plant were almost equal in all water year types (Tables O-120 and O-121). Historical loss of Pacific lamprey is infrequent; this is a driver of low values of predicted loss.

Summary

Alternative 4 and the No Action Alternative are expected to have similar impacts on the entrainment of Pacific lamprey at CVP Jones Pumping Plant, but the species is infrequent at the facility. No impacts at the SWP Banks Pumping Plant are expected.

O.7.18 Western River Lamprey

O.7.18.1 Sacramento River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Red Bluff Diversion Dam and below Keswick Dam are largely similar to those under the No Action Alternative (Table O-266 and Table O-267). Impacts on Western River lamprey spawning and egg incubation are expected to be minimal. Flows under Alternative 4 are largely the same as those under the No Action Alternative. The greatest changes in the spawning period are several flow decreases in critically dry years. However, flows are expected to remain high enough that redds should not face dewatering, and spawning and egg incubation will likely not see any serious adverse effects. Most of these critically dry decreases come in months with more robust flows, compared to others that have weaker flow but see little change. While slight adverse impacts are possible in critically dry years, survival should not be affected and overall impacts across water-year types are expected to be minimal due to the similarity to the flows of the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Western river lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Keswick Dam and Table 305 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-122. Table O-122, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 50°F to 64°F observed range of high survival and low occurrence embryonic developmental abnormalities, there was one and zero month-water year type combinations (3.3% and 0%, respectively) with favorable results at Keswick Dam and RBDD, respectively (Table O-122). There were no month-water year type combinations with unfavorable results at Keswick Dam and RBDD. These results suggest that there would be negligible water temperature-related impacts of Alternative 4 on Western River lamprey spawning and egg incubation in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible to minor adverse impacts on Western River lamprey spawning and egg incubation due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have negligible water-temperature-related impacts on Western River lamprey spawning and egg incubation in the Sacramento River.

Ammocoete Rearing and Emigration

Western river lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the Sacramento River below Redd Bluff Diversion Dam and below Keswick Dam are mostly similar to those under the No Action Alternative (Table O-266 and Table O-267). Impacts on Western River lamprey ammocoete rearing and emigration are likely to be minimal. Ammocoete rearing could see some minor adverse effects in critically dry years, as flows decrease in some spring and summer months, but flow values are expected to remain high enough that survival should not be threatened. Minor increases in some fall and winter months could have slight beneficial impacts. Overall, ammocoete rearing would likely see some minimal beneficial and adverse impacts compared to the No Action Alternative. Western River lamprey juvenile emigration is likely to also see minimal impacts from flow changes under Alternative 4. Some slight flow increases in fall and winter months during the emigration period could have minimal beneficial impacts during the emigration period, but flows are largely similar to those under the No Action Alternative, and overall impacts are expected to be minimal.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Western river lamprey year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 304 for Keswick Dam and Table 305 for Red Bluff Diversion Dam.

Results for the analysis are summarized in Table O-123. Table O-123, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 72°F observed range of high survival and low occurrence of developmental abnormalities, there were no month-water year type combinations (0% of total combinations during the period) with favorable and unfavorable results at both Keswick Dam and RBDD (Table O-123). These results suggest that there would be negligible water temperature-related impacts of Alternative 4 on Western river lamprey ammocoete rearing and emigration in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible to minor beneficial impacts on Western River lamprey ammocoete rearing and emigration due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on Western River lamprey ammocoete rearing and emigration in the Sacramento River due to differences in water temperatures.

O.7.18.2 Lower American River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates of monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 4 are somewhat similar to the No Action Alternative (Table O-277 and Table O-278). Impacts on Western River lamprey spawning are likely to be fairly small in scope due to there being little change for many months. The greatest impacts are likely to be in critically dry years (up to 23% below Nimbus), which see flow decreases in the majority of months. These decreases could have an adverse impact in March, April, and August, which would affect the beginning and end of the spawning period. While Alternative 4 would see increased flows for some water year types in April, May, and July, these would likely not have a great impact on spawning. Thus, the overall impact on spawning is likely to be slightly adverse due to the slight flow decreases in critically dry years.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in Western river lamprey during February through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 83 for Hazel Avenue and Table 84 for Watt Avenue.

Results for the analysis are summarized in Table O-124. Table O-124, as described in Section O.4.18.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in western river lamprey spawning and egg incubation under Alternative 4, there were zero and three month-water year type combinations (0.0% and 10.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-124). There were three and one month-water year type combinations (10.0% and 3.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 4, there would be positive (10% favorable) and negative (3.3% to 10% favorable) water temperature-related impacts to Western River lamprey spawning and egg incubation in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial to adverse impacts on spawning and egg incubation. Alternative 4 relative to the No Action Alternative is expected to have beneficial and adverse water-temperature-related impacts on Western River lamprey spawning and egg incubation in the lower American River.

Ammocoete Rearing and Emigration

Western River lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates for monthly flows in the lower American River at H Street and below Nimbus Dam for Alternative 4 are somewhat similar to the No Action Alternative (Table O-277 and Table O-278). Impacts on Western River lamprey ammocoete rearing are likely to be slightly adverse, as flows decrease in many months of critically dry years. While these decreases are not large, they happen at the most vulnerable times for ammocoetes, when conditions are driest. Impacts of flow changes from Alternative 4 on Western River lamprey juvenile emigration are likely to be minimal, as flows are fairly similar to those under the No Action Alternative. While flows do decrease in critically dry years compared to the No Action Alternative which has the potential to adversely affect emigration in the winter-early summer window, these decreases are relatively small and will likely not adversely affect emigration much more than flows under the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 85 for Hazel Avenue and Table 86 for Watt Avenue.

Results for the analysis are summarized in Table O-125. Table O-125, as described in Section O.4.18.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey ammocoete rearing and emigration under Alternative 4, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-125). There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that under Alternative 4, there would be negligible water temperature-related impacts to Western River lamprey ammocoete rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible to minor adverse impacts on Western River lamprey ammocoete rearing and emigration due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have negligible water temperature-related impacts on Western River lamprey ammocoete rearing and emigration in the lower American River.

O.7.18.3 Stanislaus River

Spawning and Egg Incubation

The life history of river lamprey is understudied, especially in California (Moyle et al. 2015). Spawning is believed to occur February through May in small tributary streams (Moyle 2002), with peak spawning thought to mirror that of Pacific lamprey and occur in April. Redds are built at the upstream end of small riffles (Moyle 2002), and eggs hatch typically after several weeks. Water flow and temperature impacts on eggs may occur February-July but are likely primarily April-May.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates of monthly flows in the Stanislaus River at the mouth and below Goodwin Dam for Alternative 4 compared to the No Action Alternative are a mix of increases and decreases (Table O-279 and Table O-280). Impacts on Western River lamprey spawning are likely to be similarly mixed. Flow decreases in some water year types from April through June would likely have some adverse impacts on spawning, as April and May are peak spawning months. However, flows are expected to increase during June through August in critically dry

years, which would likely be beneficial to spawning, possibly increasing spawning success and decreasing egg mortality. Overall, impacts from flow changes on spawning are likely to be mixed, with some adverse impacts in the peak spawning period but beneficial impacts in critically dry summers.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 50°F to 64°F observed range of high survival and low occurrences of embryonic developmental abnormalities in Western river lamprey during February through July are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 65 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-126. Table O-126, as described in Section O.4.18.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 50°F to 64°F observed range for high survival and low occurrences of embryonic developmental abnormalities of Western river lamprey, there were zero month-water year type combinations (0.0%) with favorable results and one combination (3.3%) with unfavorable results at Orange Blossom Bridge (Table O-126).

These results suggest that Alternative 4 would have negligible water temperature related impacts on Western River lamprey spawning and egg incubation in the Stanislaus River at Orange Blossom Bridge.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial to adverse impacts on Western River lamprey spawning and egg incubation due to differences in flow. Alternative 4 relative to the No Action Alternative is expected to have negligible water temperature-related impacts on Western River lamprey spawning and egg incubation in the Stanislaus River.

Ammocoete Rearing and Emigration

Western River lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 estimates of monthly flows in the Stanislaus River at the mouth and below Goodwin Dam for Alternative 4 compared to the No Action Alternative are a mix of increases and decreases (Table O-279 and Table O-280). Impacts on Western River lamprey ammocoete rearing are likely to be mixed as well, with decreased flows in some spring and early summer months (depending on water year type) but increased flows for some water year types in other months, and a number of months seeing flow increases in critically dry years. These increases in critically dry years could be very beneficial to ammocoete rearing, decreasing the risk of ammocoete mortality when flows are typically lowest. Impacts of flow changes on juvenile emigration are likely to be mixed as well. Flow changes are not substantial for most water year types during winter-early summer outmigration period. Flow increases during drier years in February, while flow decreases during some water years in April and January. Effects are therefore mixed, with some beneficial impacts and some adverse impacts.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 72°F upper limit for high survival and low occurrence of developmental abnormalities in Western river lamprey year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 66 for Orange Blossom Bridge and Table 67 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-127. Table O-127, as described in Section O.4.18.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 72°F upper limit for high survival and low occurrence of developmental abnormalities for Western River lamprey, there were no month-water year type combinations (0.0%) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River (Table O-127). There were zero and one month-water year type combinations (0.0% and 1.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 4 would have negligible water temperature related impact on Western River lamprey ammocoete rearing and emigration in the Stanislaus River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial to adverse impacts on Western River lamprey ammocoete rearing and emigration. Alternative 4 and the No Action Alternative is expected to have negligible water temperature-related impacts on Western River lamprey ammocoete rearing and emigration in the Stanislaus River.

O.7.18.4 San Joaquin River

Ammocoete Rearing and Emigration

Western River lamprey rearing takes place over multiple years. After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juveniles (macropthalmia) migrate downstream in the following year from May to July (Moyle 2002). Ammocoete presence for years after spawning means they are affected by water flow and temperature variations year-round, and juveniles are partially dependent on May-July flows to help their migration out of rearing territory.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 estimates for monthly flows in the San Joaquin River at Vernalis for Alternative 4 are largely unchanged compared to the No Action Alternative (Table O-281). Impacts on Western River lamprey ammocoete rearing are likely to be slightly beneficial. Increased flows during summer months of critically dry years would be beneficial and would decrease the risk of ammocoete habitat being dewatered, increasing success and survival. Otherwise, impacts on ammocoete rearing are likely to be minimal as flows are largely unchanged. Impacts on Western River lamprey juvenile emigration are likely to be minimal. Flows during the emigration period are mostly unchanged compared to the No Action Alternative, and there would be no impact on emigration.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on Western River lamprey in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

<u>Summary</u>

Alternative 4 relative to the No Action Alternative is expected to have beneficial impacts on Western River lamprey ammocoete rearing and emigration in the San Joaquin River due to differences in flow. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year and likely to have negligible impacts.

O.7.18.5 Bay-Delta

The Sacramento and San Joaquin River Basins are at the southern edge of the range for Western River lamprey (Moyle et al. 2009). While their population abundance is poorly understood, they are frequently caught in the Delta Juvenile Fish Monitoring Program in the winter months through trawls at Sherwood Harbor, Mossdale, and Chipps Island (Interagency Ecological Program et al. 2022). Ammocoetes spend an unknown amount of time as ammocoetes (likely 3-5 years) in silt-sand backwater eddies and have been documented during dredging studies in the Delta (Lamprey Technical Workgroup 2021; Moyle et al. 2015). Adults typically start their migration back into their natal habitats in the fall.

Potential Changes to Western River Lamprey from Seasonal Operations

CalSim 3 Flows

CalSim 3 models predict that flows in the Bay-Delta under Alternative 4 would see a mix of increases and decreases compared to the No Action Alternative (Table O-274). For impacts in the southern Delta, see the San Joaquin River section above, which discusses flow at Vernalis. Under Alternative 4, flows at Rio Vista would see a mix of increases and decreases but would be relatively unchanged compared to the No Action Alternative. Similar to Pacific lamprey, impacts on Western river lamprey ammocoete rearing would likely be negligible, as flows are likely adequate for rearing. Impacts on juvenile emigration would be beneficial in April of critically dry water year types. Impacts on adult migration would be negligible, as flows are similar (less than a 5% difference) throughout the fall of critically dry water year types.

Summary

Alternative 4 relative to the No Action Alternative is expected to have beneficial impacts on Western river lamprey juvenile emigration in April of critically dry water year types and negligible impacts on adult migration due to differences in flow. Impacts on ammocoete rearing is expected to be negligible.

Potential Changes to Entrainment of Western River Lamprey

Salvage Density

Predictions from the salvage density model for Western River lamprey include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Whereas at the SWP Banks Pumping Plant no loss was anticipated for any water year types for any alternative, predicted average monthly loss of Western River lamprey of Alternative 4 compared to the No Action Alternative at CVP Jones Pumping Plant was minor in all water year types, except in dry water year types when no fish are expected (Tables O-128 and O-129). At the CVP Jones Pumping Plant predicted average monthly loss was up to 3% greater in February through March of critically dry water year types and as low as -3% less in January of below normal water year types (Table O-129). Historical loss of Western river lamprey is infrequent; this is a driver of low values of predicted loss.

Summary

Alternative 4 relative to the No Action Alternative is expected to have adverse and beneficial impacts on the entrainment of Western river lamprey at CVP Jones Pumping Plant due to differences in exports, but the species is infrequent at the facility. No impacts at the SWP Banks Pumping Plant are expected.

O.7.19 Striped Bass

O.7.19.1 Sacramento River

Spawning and Egg Incubation

It is believed that striped bass do not spawn or rear in the Sacramento River upstream of RBDD (Tehama-Colusa Canal Authority 2008). Most spawning in the Sacramento River occurs in the lower river between Colusa and the confluence of the Sacramento and Feather Rivers (Moyle 2002). About one-half to two-thirds of adults spawn in the Sacramento River and the remainder spawn in the Delta (Leet et al. 2001). After spawning, most adult striped bass move downstream into brackish and salt water for summer and fall (Moyle 2002).

Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

Potential Changes to Striped Bass from Seasonal Operations

<u>CalSim 3 Flows</u>

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows at Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤ 4%) increases and/or decreases are April through June; this suggests habitat will remain similar to the No Action Alternative (Table O-267 through Table O-269).

<u>Water Temperature Analysis</u>

Full results of the analysis assessing the percent of months with water temperature outside the 59°F to 68°F optimal water temperature range for spawning, embryo incubation and initial rearing for striped bass during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 317 for Butte City.

Results for the analysis are summarized in Table O-130. Table O-130, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 59°F to 68°F optimal water temperature range, there was one month-water year type combinations (6.7 % of total combinations during the period) with favorable and unfavorable results at Butte City (Table O-130). These results suggest that there would be negligible water temperature-related effects of Alternative 4 on striped bass spawning and egg incubation in the Sacramento River.

Summary

Overall, under Alternative 4 compared to the No Action Alternative for CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will remain similar to the No Action Alternative. The optimal water temperature range analysis predicts 6.7% of month-water year type combinations would have favorable or unfavorable results. Overall, these results suggest there would be negligible flow impacts on spawning habitat and negligible water temperature-related impacts on striped bass spawning and egg incubation in the Sacramento River under Alternative 4 compared to the No Action Alternative.

Larval and Juvenile Rearing and Emigration

During this early period the embryos and larvae in the Sacramento River are carried into the Delta and Suisun Bay (Moyle 2002). YOY striped bass distribute themselves in accordance with the estuarine salinity gradient (Kimmerer 2002a; Feyrer et al. 2007), indicating that salinity is a major factor affecting their habitat use and geographic distributions. Kimmerer (2002a) found that distributions of fish species, including striped bass, substantially overlapped with the low-salinity zone. Older individuals are increasingly flexible about their distribution relative to salinity (Moyle 2002). Statistically significant correlations between indices of age-0 abundance or survival in the San Francisco Estuary and Delta have been found with Delta outflow (which can be approximated by X2, the distance in km from the Golden Gate Bridge at which bottom salinity is 2 psu) (e.g., Kimmerer et al. 2009; Mac Nally et al. 2010), with evidence for greater extent of habitat as the mechanism (Kimmerer et al. 2009). However, subsequent density-dependent survival after the first summer dampens the effects of flow on subsequent recruitment (Kimmerer et al. 2000).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows at Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤ 4%) increases and/or decreases are most months; this suggests habitat will remain similar to the No Action Alternative (Table O-267 through Table O-269).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F range of optimal temperatures for larvae, fry, and juvenile rearing and emigration year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 318 for Butte City.

Results for the analysis are summarized in Table O-131. Table O-131, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 61°F to 71°F optimal water temperature range for larvae, fry, and juvenile rearing and emigration, there were two month-water year type combination (3.3% of total combinations during the period) with favorable results at Butte City (Table O-131). There were zero combinations (0.0%) with unfavorable results at Butte City. These results suggest that there would be negligible positive water temperature-related impacts from Alternative 4 on striped bass larvae, fry, and juvenile rearing and emigration in the Sacramento River.

Summary

Overall, Alternative 4 compared to the No Action Alternative for CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will remain similar to the No Action Alternative. The optimal water temperature range analysis predicts that 3.3% month-water year type combinations would have favorable results at Butte City. Overall, these results suggest there would be negligible flow and water temperature-related impacts on striped bass juvenile rearing and emigration habitat in the Sacramento River under Alternative 4 compared to the No Action Alternative.

O.7.19.2 Lower American River

Adults

Striped bass are present in the lower American River throughout the year, with the greatest abundance in summer (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam and in the lower American River at H Street indicate that minor (≤ 7%) increase and/or decrease is estimated nearly all months in a given year (Table O-276 through Table O-278). These results suggest habitat will remain similar nearly all months of the year under Alternative 4 compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 77°F stress initiation value for adult striped bass year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 93 for Hazel Avenue and Table 94 for Watt Avenue.

Results for the analysis are summarized in Table O-132. Table O-132, as described in Section O.4.19.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 77°F stress initiation water temperature value for adult striped bass under Alternative 4, there were 0 month-water year type combinations (0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-132). There were also 0 month-water year type combinations (0%) with unfavorable results at Hazel Avenue and Watt Avenue.

These results suggest that under Alternative 4, there would be negligible water temperature-related effects to adult striped bass in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling flows suggests spawning habitat will remain similar to the No Action Alternative. The optimal water temperature range modeling estimates indicate there are no combinations with beneficial or adverse results at Butte City. Overall, these results suggest there would be generally negligible flow impacts on adult habitat and negligible water temperature-related impacts on adult striped bass in the lower American River at Hazel Avenue and Watt Avenue under Alternative 4 compared to the No Action Alternative.

Juvenile Rearing

Although the occurrence of spawning in the lower American River is uncertain, the river is believed to serve as a nursery area for YOY and subadult striped bass (Surface Water Resources 2001). Striped bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam and in the lower American River at H Street indicate that minor (≤ 7%) increase and/or decrease is estimated nearly all months in a given year (Table O-277 and Table O-278). These results suggest striped bass habitat will remain similar nearly all months of the year under Alternative 4 compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing year-round are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 95 for Hazel Avenue and Table 96 for Watt Avenue.

Results for the analysis are summarized in Table O-133. Table O-133, as described in Section O.4.19.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 61°F to 71°F optimal range for juvenile striped bass rearing under Alternative 4, there were one and four month-water year type combinations (1.7% and 6.7%, respectively) with

favorable results at both Hazel Avenue and Watt Avenue, respectively (Table O-133). There were three month-water year type combinations (5.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that under Alternative 4, there would be positive and negative water temperature-related impacts to juvenile striped bass rearing in the lower American River.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and water temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat will remain similar to the No Action Alternative. Overall, these results suggest there would be generally negligible flow impacts and adverse and beneficial water temperature-related impacts to juvenile striped bass rearing in the lower American River at Hazel Avenue and Watt Avenue.

O.7.19.3 Stanislaus River

Spawning and Egg Incubation

Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. These adult fish were observed in all habitats (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (U.S. Fish and Wildlife Service 2002).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 4 compared to the No Action Alternative CalSim 3 flow results show minor (≤ 5%) and decreases in flow at Goodwin Dam and mouth of the Stanislaus River, except in April when flow is expected to decrease (8%) at Goodwin Dam (Table O-279 and Table O-280). These results suggest flows may have adverse impacts on striped bass in April.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature above the 59°F to 68°F optimal range of water temperature for spawning, embryo incubation, and initial rearing of striped bass for April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 70 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-134. Table O-134, as described in Section O.4.19.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 59°F to 68°F optimal range of water temperature for spawning, embryo incubation, and initial rearing of striped bass, there was one month-water year type combination (6.7%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-134).

These results suggest that Alternative 4 would have negligible water-temperature related effects on striped bass spawning, embryo incubation, and initial rearing at Orange Blossom Bridge in the Stanislaus River.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests flows may have adverse impacts in April. The optimal water temperature range modeling estimates indicate a 6.7% month-water year type combination with beneficial results and no combinations with adverse results at Orange Blossom Bridge. Overall, these results generally suggest adverse flow impacts in April and negligible water temperature-related impacts to striped bass spawning and egg incubation in the Stanislaus River at Goodwin Dam and the mouth under Alternative 4 compared to the No Action Alternative.

Larval and Juvenile Rearing and Emigration

Striped bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. The distribution of striped bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (U.S. Fish and Wildlife Service 2002).

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows show minor (≤ 1%) to slight (≤ 10%) increases in flow and minor (≤1%) to slight (8%) decreases in flow at Goodwin Dam and mouth of the Stanislaus River (Table O-279 and Table O-280). At Goodwin Dam, slight (≤ 10%) increases are generally expected in February, July, August, and December and a slight (8%) decrease generally April. At the mouth, a slight (7%) increase is generally expected in August. These results suggest averaged flows may be generally beneficial on striped bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 71 for Orange Blossom Bridge and Table 72 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-135. Table O-135, as described in Section O.4.19.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 61°F to 71°F water temperature optimal range for striped bass juvenile rearing there were zero and two month-water year type combinations (0.0% and 3.3%) with favorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-135). There were zero and four month-water year type

combinations (0.0% and 6.7%, respectively) with unfavorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively.

These results suggest that Alternative 4 would have negligible water temperature-related effects on juvenile striped bass rearing in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests flows may have generally beneficial impacts. The optimal water temperature range modeling estimated 3.3% beneficial and 6.7% with adverse results month-water year type combinations above the confluence with the San Joaquin River. Overall, these results generally suggest beneficial flow impacts and adverse water temperature related impacts on juvenile striped bass rearing in the Stanislaus River.

O.7.19.4 San Joaquin River

Striped bass are regularly found in San Joaquin River tributaries, including in lower mainstem deep pools of the Stanislaus and Tuolumne Rivers (e.g., Anderson et al. 2007). Ainsley et al. (2013) reported that striped bass were collected at two locations between the Head of the Old River and the mouth of the Stanislaus River on the mainstem San Joaquin River in May. In the San Joaquin River outflow is balanced by tidal currents, so that embryos and larvae stay suspended in the same general area in which spawning took place. Essentially, larval bass from both rivers are most abundant where salt and fresh water meet. Thus, when they begin to feed they are concentrated in the most productive portions of the entire estuary. Larval growth and survival rates are also highest in areas of brackish water, presumably because of reduced energy costs for osmoregulation (Moyle 2002).

Potential Changes to Striped Bass from Seasonal Operations

Alternative 4 compared to the No Action Alternative CalSim 3 modeling results show minor (≤ 5%) increases and decreases in flow are estimated nearly all months at Vernalis; slight (≤ 8%) to moderate (≤ 22%) flow increases are anticipated generally in June through September of critically dry water years (Table O-281). The greatest increases are expected on average in July through August (21% and 22%, respectively) of critically dry water years. These results suggest averaged flows are generally similar, except during critically dry water years when flows would be higher under Alternative 4 compared to the No Action Alternative; this suggests a beneficial effect on striped bass.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on striped bass in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 4 compared to the No Action Alternative CalSim 3 results are generally similar, except in critically dry water years when flows would be higher under Alternative 4; this suggests beneficial impacts on striped bass during critically dry water years. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.7.19.5 Bay-Delta

Striped bass use the Delta as a migratory route and for rearing and seasonal foraging. Striped bass spend the majority of their lives in salt water, returning to freshwater to spawn. Adult striped bass spend about 6 to 9 months of the year in San Francisco and San Pablo Bays (Hassler 1988). Striped bass also use deeper areas of many of the larger channels in the Delta, in addition to large embayments such as Suisun Bay.

Spawning occurs in spring, primarily in the Sacramento River between Sacramento and Colusa and in the San Joaquin River between Antioch and Venice Island (Farley 1966). Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all striped bass eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

Potential Changes to Striped Bass from Seasonal Operations

CalSim 3 Flows

Alternative 4 compared to the No Action Alternative CalSim 3 modeling results show minor (≤ 5%) to substantial (≤ 54%) increases in flow and minor (5%) to slight (≤ 11%) decreases in flow in the Bay-Delta (Tables O.6-9, O.6-10, and O.6-11). At SWP and CVP exports, slight (8%, February) to moderate (25%, May) flow increases and slight (≤ 12%, December) are expected. At the confluence of Old and Middle River in the Delta, slight (16%, February) to substantial (≤ 54%, May) flow increases and slight (≤ 16%, December) are expected. For Delta outflow, a slight (6%) decrease in flow is generally expected in May. These differences suggest flows may have beneficial impacts on striped bass.

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for striped bass indicated that the overall average abundance index for Alternative 4 although essentially similar to the No Action Alternative, would likely be the lowest when compared across all water year types (-3% to +2%).

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and Delta outflow modeling results had some differences. The differences determined by CalSim 3 modeling suggests flows may have generally beneficial impacts on striped bass. Predictions from the Delta Outflow species abundance modeling for striped bass indicated that the overall average abundance index for Alternative 4 would be similar to the No Action Alternative all water year types. Overall, these results suggest generally beneficial flow impacts on striped bass under Alternative 4.

Potential Changes to Entrainment of Striped Bass

Predictions from the salvage density model for striped bass include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of striped bass under Alternative 4 compared to the No Action Alternative at the SWP Banks Pumping Plant were generally similar or higher and CVP Jones Pumping Plant were generally similar or lower all water year types (Tables O-136 and O-137). At the SWP Banks Pumping Plant predicted average monthly loss was up to 5% higher on critically dry (Table O-136). At CVP Jones Pumping Plant predicted average monthly loss was up to 10% and 8% lower on dry and critically dry water years (Table O-137).

Summary

Overall, Alternative 4 compared to the No Action Alternative salvage density modeling results had some differences. The salvage density modeling predicted monthly loss under Alternative 4 are similar most water year types, except at SWP Banks Pumping Plant in critically dry water years when loss would have a minor (5%) increase and at CVP Jones Pumping Plant in dry and critically dry water year types when loss would have slight (≤ 10%) decreases. Overall, loss increases and decreases at SWP and CVP Delta facilities (respectively) from entrainment are anticipated under Alternative 4.

O.7.20 American Shad

O.7.20.1 Sacramento River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River. Migrating adults generally take 2 to3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Keswick Dam under Alternative 4 range from about 3,500 cfs for March in critically dry years to 24,000 cfs for February of wet water years (Table O-266). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. This increase in flows could result in more eggs and larval fish to be washed further downstream earlier than expected but Alternative 4 cannot be determined to have adverse effects. Therefore, Alternative 4 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 319 for Butte City.

Results for the analysis are summarized in Table O-138. Table O-138, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 62°F to 75°F optimal range, there were no month-water year type combinations (0% of total combinations during the period) with favorable or unfavorable results at Butte City (Table O-138). These results suggest that there would be negligible water temperature-related impacts from Alternative 4 on American shad spawning and larval rearing in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is largely expected to have negligible impacts on American shad spawning and larval rearing below Keswick Dam in the Sacramento River due to differences in flow. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation under Alternative 4 compared to the No Action Alternative will have a negligible impact on American shad spawning and larval rearing in the Sacramento River. Therefore, the differences in flow and temperature under Alternative 4 compared to the No Action Alternative in the Sacramento River are expected to have negligible impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

In the Sacramento River, summer rearing habitat occurs in the main river from Colusa to the north Delta (Stevens et al. 1987). As the season progresses, juvenile American shad move downstream and enter salt water primarily during September through November (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Keswick Dam under Alternative 4 range from about 4,000 cfs for October in critically dry years to 9,000 cfs for September of wet water years (Table O-266). Because American shad are anadromous fish that migrate great lengths to reach their spawning grounds, these flow levels are likely to be adequate for juvenile rearing and emigration, so no adverse effects are expected to result. Alternative 4 is higher (16%) in November of critically dry years (Table O-266). Alternative 4 would likely have negligible flow impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F range optimal range for juvenile rearing and emigration during July through November are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 320 for Butte City.

Results for the analysis are summarized in Table O-139. Table O-139, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 62°F to 75°F optimal range, there were four month-water year type combination (16.0% of total combinations during the period) with favorable results at Butte City (Table O-139). There were zero unfavorable results at Butte City. These results suggest that there would be positive water temperature-related effects of Alternative 4 on American shad juvenile rearing and emigration in the Sacramento River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have little impact on American shad juvenile rearing and emigration in the Sacramento River due to differences in flow. Flow for rearing and emigration is not a limiting factor for American shad. Water temperatures for larval rearing and emigration under Alternative 4 compared to the No Action Alternative would have beneficial impacts on American shad juvenile rearing and emigration in the lower American River.

O.7.20.2 Lower American River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento River. Migrating adults generally take two to three months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962).

Adult American shad migrate into the lower American River to spawn during the late spring, typically during April through early July (California Department of Fish and Wildlife 1986).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Nimbus Dam and H street under Alternative 4 range from about 788 cfs for April at H St. in critically dry years to 12,307 cfs at H St. for February of wet water years (Table O-277 and Table O-278). Differences in flows between Alternative 4 and the No Action Alternative are generally minimal in these months below Nimbus Dam and at H St. with a reduction of flow (~24%) in March of critically dry years (Table O-277 and Table O-278). Because American shad spawn in depths from 1m to 10 m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. This decrease in flows could result in a reduction in adequate spawning habitat but Alternative 4 cannot be determined to have adverse effects. Therefore, Alternative 4 would likely have minimal flow effects on American shad spawning and larval rearing relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range for American shad spawning and larval rearing during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 97 for Hazel Avenue and Table 98 for Watt Avenue.

Results for the analysis are summarized in Table O-140. Table O-140, as described in Section O.4.20.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 62°F to 75°F optimal range for American shad spawning and larval rearing under Alternative 4, there were two and one month-water year type combinations (13.3% and 6.7%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively (Table O-140). There were zero and one month-water year type combinations (0.0% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 4, there would be positive and negative water temperature-related impacts to American shad spawning and larval rearing in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on American shad spawning and larval rearing below Nimbus Dam and at H Street due to differences in flow. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation from Hazel Avenue and Watt Avenue under Alternative 4 compared to the No Action Alternative will have beneficial and adverse impacts on American shad spawning and larval rearing in the lower American River. Therefore, the differences in flow and water temperature under Alternative 4 compared to the No Action Alternative in the lower

American River are expected to have some beneficial and adverse impacts on American shad spawning and larval rearing.

Juvenile Rearing and Emigration

American shad rearing and emigration in the lower American River is dependent on water temperatures. August through September, but before November, are optimal months for juvenile American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Nimbus Dam and H street under Alternative 4 range from about 583 cfs at H Street for October in critically dry years to 4,254 cfs below Nimbus Dam for November of wet water years (Table O-277 and Table O-278). Differences in flows between Alternative 4 and the No Action Alternative are slightly lower (~9%) for Alternative 4 below Nimbus Dam and at H Street in October and November during critically dry years (Table O-277 and Table O-278) Because American shad are anadromous fish that migrate great lengths to reach their spawning grounds, these flow levels are likely to be adequate for juvenile rearing and emigration, so no adverse effects are expected to result. Therefore, Alternative 4 would likely have negligible impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for American shad juvenile rearing and emigration during July through November are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 99 for Hazel Avenue and Table 100 for Watt Avenue.

Results for the analysis are summarized in Table O-141. Table O-141, as described in Section O.4.20.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 63°F to 77°F optimal range for American shad spawning and larval rearing under Alternative 4, there were two month-water year type combinations (8.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-141). There were three and zero month-water year type combinations (12.0% and 0.0%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively.

These results suggest that under Alternative 4, there would be positive and negative water temperature-related impacts to American shad juvenile rearing and emigration in the lower American River at Hazel Avenue and Watt Avenue.

Summary

Alternative 4 relative the No Action Alternative is largely expected to have negligible impacts on American shad juvenile rearing and emigration due to differences in flow. Flow for rearing and emigration is not a limiting factor for American shad. Water temperatures for larval rearing and emigration at Hazel Avenue and Watt Avenue under Alternative 4 compared to the No Action Alternative would have beneficial adverse impacts on American shad juvenile rearing and emigration in the lower American River. Therefore, the differences in flow and water temperatures under Alternative 4 compared to the No Action Alternative are expected to have beneficial and adverse impacts on American shad juvenile rearing and emigration.

O.7.20.3 Stanislaus River

Spawning and Larval Rearing

American shad migrate up the Stanislaus River to spawn in the late spring and support a sport fishery during that period. American shad have been observed on occasion from June through July at Lovers Leap (U.S. Fish and Wildlife Service 2002; Kennedy and Cannon 2005). American shad were found primarily in the faster habitats and were observed in schools of 20 or more (U.S. Fish and Wildlife Service 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the February to April adult American shad migration into Delta, CalSim 3 estimates of mean monthly flows below Goodwin Dam and Stanislaus River mouth under Alternative 4 range from about 200 cfs for March in critically dry years to 2200 cfs for February below Goodwin Dam and at Stanislaus River Mouth of wet water years (Table O-279 and Table O-280). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Differences in flows between Alternative 4 and the No Action Alternative are about 45% higher for Alternative 4 in February below Goodwin Dam in dry and critically dry years and 10% higher in February and March at the Stanislaus River Mouth for dry and critically dry water years (Table O-279 and Table O-280) Alternative 4 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 62°F to 75°F optimal range for American shad spawning and larval rearing during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 73 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-142. Table O-142, as described in Section O.4.20.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 59°F to 68°F 62°F to 75°F optimal range for American shad spawning and larval rearing, there was one month-water year type combinations (6.7%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-142).

These results suggest that Alternative 4 would have negligible water-temperature related effects on American shad spawning and larval rearing at Orange Blossom Bridge in the Stanislaus River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on American shad spawning and larval rearing due to differences in flow. Flow for spawning is not a limiting factor for American shad. Water temperatures for spawning initiation at Orange Bridge Dam and above the confluence under Alternative 4 compared to the No Action Alternative will have negligible water temperature-related impacts on American shad spawning and larval rearing at Orange Blossom Bridge in the Stanislaus River.

Juvenile Rearing and Emigration

American shad rearing and emigration in the Stanislaus River is dependent on water temperatures. From Orange Blossom Bridge to just above the confluence, juvenile rearing and emigration generally occur in July for American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

CalSim 3 Flows

During the September to November juvenile American shad emigration back into Delta, CalSim 3 estimates of mean monthly flows below Goodwin Dam and Stanislaus River Mouth under Alternative 4 range from about 200 cfs for September in critically dry years to 800 cfs in September and October below Goodwin Dam and Stanislaus River Mouth during wet water years (Table O-279 and Table O-280). Differences in flows between Alternative 4 and the No Action Alternative are unchanged for Alternative 4 below Goodwin Dam and 29% higher at Stanislaus River Mouth in September during critically dry years (Table O-279 and Table O-280). With no change below Goodwin Dam and an increase in flows at Stanislaus River Mouth, American shad could see no adverse effects from Alternative 4. Therefore, Alternative 4 would likely have negligible impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for American shad juvenile rearing and emigration during July through November are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 74 for Orange Blossom Bridge and Table 75 for above the confluence with the San Joaquin River.

Results for the analysis are summarized in Table O-143. Table O-143, as described in Section O.4.20.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 63°F to 77°F optimal range for American shad juvenile rearing and emigration there were zero and one month-water year type combinations (0.0% and 4.0%, respectively) with favorable results at Orange Blossom Bridge and above the confluence with the San Joaquin River, respectively (Table O-143). There were zero month-water year type combinations (0.0%) with unfavorable results at both Orange Blossom Bridge and above the confluence with the San Joaquin River.

These results suggest that Alternative 4 would have negligible negative water temperature related impacts on American shad juvenile rearing and emigration in the Stanislaus River at Orange Blossom Bridge and above the confluence with the San Joaquin River.

Summary

Alternative 4 relative to the No Action Alternative is expected to have negligible impacts on American shad juvenile rearing and emigration due to flow differences. Flow for rearing and emigration is not a limiting factor for American shad. Water temperatures for larval rearing and emigration at Orange Blossom Bridge and above the confluence under Alternative 4 compared to the No Action Alternative are suggested to have negligible water temperature-related impacts on American shad juvenile rearing and emigration in the Stanislaus River.

O.7.20.4 San Joaquin River

Spawning and Larval Rearing

American shad is an anadromous fish that spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas. Migrating adults generally take 2 to3 months to pass through the Delta starting as early as February (Painter et al. 1979). Most adults migrate into the Delta in March and early April (Skinner 1962).

Little is known about American shad populations inhabiting the San Joaquin River. American shad may spawn in the San Joaquin River system, but their abundance is unknown.

Potential Changes to American Shad from Seasonal Operations

During the February to April adult American shad migration into the Delta, CalSim 3 estimates of mean monthly flows in the San Joaquin River at Vernalis under Alternative 4 range from about 2,000 cfs for March critically dry years to 13,000 cfs for February (Table O-281). Because American shad spawn in depths from 1m to 10m, typically less than 3m (Moyle 2002), these flow levels are likely to be adequate for spawning and incubation. Differences in flows between Alternative 4 and the No Action Alternative are slightly higher (~1%) for Alternative 4 in February and March of critically dry water years (Table O-281) Alternative 4 would likely have negligible flow impacts on American shad eggs and embryos relative to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on American shad spawning and larval rearing in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the American shad spawning and larval rearing period (Figure O-15).

Summary

There may be negligible impacts from seasonal operations on American shad spawning and larval rearing based on analyses of simulated flows under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are unlikely to impact American shad juvenile rearing and non-spawning adult. Under Alternative 4, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the American shad spawning and larval rearing period.

Juvenile Rearing and Emigration

American shad rearing and emigration is dependent on water temperatures. Generally, juvenile rearing and emigration generally occur in July for American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

During the September to November juvenile American shad emigration back into the Delta, CalSim 3 estimates of mean monthly flows in the San Joaquin River at Vernalis under Alternative 4 range from about 800 cfs for September in critically dry years to 2,900 cfs for October and November in the San Joaquin River at Vernalis of wet water years (Table O-281) Differences in flows between Alternative 4 and the No Action Alternative are slightly higher (10%) for Alternative 4 in September in the San Joaquin River at Vernalis during critically dry years (Table O-281). With these flows, American Shad should not feel any adverse effects from Alternative 4. Therefore, Alternative 4 would likely have negligible impacts on American shad juvenile rearing and emigration relative to the No Action Alternative.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on American shad in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile rearing and emigration period (Figure O-15).

Summary

There may be negligible impacts from seasonal operations on American shad juvenile rearing and emigration based on analyses of simulated flows under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are unlikely to have impacts on American shad juvenile rearing and emigration. Under Alternative 4, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the juvenile rearing and emigration period.

O.7.20.5 Bay-Delta

American shad spend most of their adult life at sea and may make extensive migrations along the coast. American shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento, Feather, American, and Yuba Rivers. Some spawning also takes place in the lower San Joaquin, Mokelumne, and Stanislaus Rivers (U.S. Fish and Wildlife Service 1995). The spawning migration may begin as early as February, but most adults migrate into the Delta in March and early April (Skinner 1962). Migrating adults generally take 2 to 3 months to pass through the Sacramento–San Joaquin estuary (Painter et al. 1979).

American shad rearing and emigration in the Bay-Delta is dependent on water temperatures. August through September, but before November, are optimal months for juvenile American shad to start emigrating into the Delta and out into the ocean (Moyle 2002).

Potential Changes to American Shad from Seasonal Operations

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for American shad indicated that the overall abundance index for Alternative 4 would essentially be similar when compared to the No Action Alternative across all water year types (-2% to -1%, -1% overall).

Summary

There may be negligible impacts from seasonal operations on American shad abundance based on analyses of simulated flows under Alternative 4 in comparison to the No Action Alternative. American shad abundance index would be similar to the No Action Alternative across all water year types in the Bay-Delta based on the Delta Outflow model.

Potential Changes to Entrainment of American Shad

Differences in exports under Alternative 4 compared with the No Action Alternative may have effects on American shad entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for American shad include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of American shad under Alternative 4 compared to the No Action Alternative at the SWP Banks Pumping Plant was similar all water year types and CVP Jones Pumping Plant was similar most water year types (Tables O-144 and O-145). At CVP Jones Pumping Plant predicted average monthly loss decreased up to 5% on above normal water year types (Table O-145).

Summary

There may be beneficial and adverse changes to American shad entrainment based on analyses of simulated exports under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, entrainment was similar or increased at both Jones Pumping Plant and Banks Pumping Plant during February through May of all water year types and was similar or decreased in December, January, and June of all water year types when compared to the No Action Alternative.

O.7.21 Threadfin Shad

O.7.21.1 Sacramento River

Spawning for threadfin shad takes place in California April through August, peaking in June and July. The embryos hatch in 3 to 6 days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Threadfin shad are occasionally caught at the Red Bluff Diversion Dam RST in the Sacramento River, and occur year-round (Voss 2024).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Feyrer et al. (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 4 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal spawning range during April through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 321 for Butte City.

Results for the analysis are summarized in Table O-146. Table O-146, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 63°F to 77°F optimal range, there were two month-water year type combinations (8.0% of total combinations during the period) with favorable results at Butte City (Table O-146). There were no month-water year type combinations (0%) with unfavorable results at Butte City. These results suggest that there would be positive water temperature-related effects of Alternative 4 on threadfin shad spawning in the Sacramento River.

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are likely to have a negligible impact on threadfin shad. Temperature analysis predicts beneficial impacts of Alternative 4 on threadfin shad spawning in the Sacramento River.

O.7.21.2 Lower American River

Spawning for threadfin shad takes place in California April through August, peaking in June and July. The embryos hatch in 3 to 6 days and larvae immediately become planktonic. Threadfin shad are occasionally captured as part of the non-salmonid bi-catch in the RSTs in the lower American River (Pacific States Marine Fisheries Commission 2014).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Feyrer et al. (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 4 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for threadfin shad adult spawning during April through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 101 for Hazel Avenue and Table 102 for Watt Avenue.

Results for the analysis are summarized in Table O-147. Table O-147, as described in Section O.4.21.2, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

For the 63°F to 77°F optimal range for threadfin shad spawning under Alternative 4, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-147). There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that under Alternative 4, there would be negligible water temperature-related effects to threadfin shad spawning in the lower American River at Hazel Avenue and Watt Avenue.

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are likely to have a negligible impacts on threadfin shad. Temperature analysis also suggests negligible impacts from Alternative 4 on threadfin shad spawning in the lower American River.

O.7.21.3 Stanislaus River

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Threadfin shad are occasionally captured in the Caswell RST in the lower Stanislaus River (Bradbury and Hickey 2019).

Potential Changes to Threadfin Shad from Seasonal Operations

Flow Impacts

There is no strong evidence that flow influences threadfin shad abundance. While Feyrer et al. (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 4 are likely adequate for threadfin shad.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 63°F to 77°F optimal range for threadfin shad adult spawning during April through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 76 for Orange Blossom Bridge.

Results for the analysis are summarized in Table O-148. Table O-148, as described in Section O.4.21.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 63°F to 77°F optimal range for threadfin shad adult spawning, there were no month-water year type combinations (0.0%) with favorable or unfavorable results at Orange Blossom Bridge (Table O-148).

These results suggest that Alternative 4 would have negligible water-temperature related effects on threadfin shad spawning in the Stanislaus River at Orange Blossom Bridge.

Summary

There may be negligible impacts from seasonal operations on threadfin shad based on analyses of simulated flows and water temperature under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are expected to have a negligible impact on threadfin shad. The temperature analysis also suggests negligible impacts from Alternative 4 on threadfin shad spawning in the Stanislaus River.

O.7.21.4 San Joaquin River

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in 3 to 6 days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004). Juveniles can form dense schools and while they are typically abundant in freshwater, they may also be found in varying salinities throughout the estuary. Threadfin shad are fast-growing but short-lived, with an average lifespan of two years.

Potential Changes to Threadfin Shad from Seasonal Operations

There is no strong evidence that flow influences threadfin shad abundance. While Feyrer et al. (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 4 are likely adequate for threadfin shad.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impacts on threadfin shad in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

There may be negligible impacts from seasonal operations on threadfin shad juvenile rearing and non-spawning adults based on analyses of simulated flows under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, changes in flows are likely to have negligible impacts on threadfin shad spawning and larval rearing. Under Alternative 4, HEC-5Q simulated water temperatures are similar to the No Action Alternative throughout the year.

O.7.21.5 Bay-Delta

Threadfin shad spawning takes place in California April through August, peaking in June and July. The embryos hatch in three to six days and larvae immediately become planktonic. As noted by Baxter et al. (2010), threadfin shad are widely distributed but most encountered and abundant in the southeastern Delta, especially the San Joaquin River near and just downstream of Stockton. In these regions, suitable abiotic habitat coincides with high prey abundance (Feyrer et al. 2009). These regions also have a relatively high density of submerged aquatic vegetation, which provides important habitat for spawning and larval rearing (Grimaldo et al. 2004).

Potential Changes to Threadfin Shad from Seasonal Operations

There is no strong evidence that flow influences threadfin shad abundance. While Feyrer et al. (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 4 are likely adequate for threadfin shad.

Summary

There may be negligible impacts from seasonal operations on threadfin shad under Alternative 4 in comparison to the No Action Alternative.

Juvenile Rearing and Non-Spawning Adults

Threadfin shad have been established in the Sacramento–San Joaquin River system and the Delta. Threadfin shad live mainly in freshwater and become progressively less abundant as salinity increases. Juveniles can form dense schools and while they are typically abundant in freshwater, they may also be found in varying salinities throughout the estuary. Threadfin shad are fast-growing but short-lived, with an average lifespan of two years.

Potential Changes to Threadfin Shad from Seasonal Operations

There is no strong evidence that flow influences threadfin shad abundance. While Feyrer et al. (2004) found the abundance index for threadfin shad was highest during low outflow conditions it was likely due to warmer water temperatures earlier in the year during low outflow conditions which led to earlier spawning and larger populations of young-of-year fish. Other studies such as Stompe et al. (2023), showed threadfin shad abundance shifts in geographic space were non-linear with outflow in the San Francisco Estuary, likely due its ability to shift into different

regions. Analysis by Thomson et al. (2010) suggests threadfin shad are particularly vulnerable to exports because their entire lifecycle takes place in freshwater. Threadfin shad are most abundant in deep, clear, fresh water with high zooplankton abundance (Feyrer et al. 2009). Flows under Alternative 4 are likely adequate for threadfin shad.

Summary

There may be negligible impacts from seasonal operations on threadfin juvenile rearing and non-spawning adults based on analyses of simulated flows under Alternative 4 in comparison to the No Action Alternative.

Potential Changes to Entrainment of Threadfin Shad

Salvage Density

Predictions from the salvage density model for threadfin shad include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of threadfin shad under Alternative 4 compared to the No Action Alternative at the SWP Banks Pumping Plant was similar all water year types and CVP Jones Pumping Plant was similar most water year types (Table O-149 and O-150). At CVP Jones Pumping Plant predicted average monthly loss decreased up to 5% on dry water year types (Table O-150).

Summary

There may be beneficial and adverse changes to entrainment on threadfin shad juvenile rearing and non-spawning adults based on analyses of simulated exports under Alternative 4 in comparison to the No Action Alternative. Under Alternative 4, entrainment increased at Banks during the wet, above normal, and below normal water year types and decreased during the dry and critically dry water year type, while entrainment at Jones decreased during the wet year type, was negligible for the above normal and below normal water year types and decreased during the dry and critically dry water year types.

O.7.22 Black Basses

O.7.22.1 Three Micropterus spp.

Three *Micropterus* spp. constitute the group of black basses in California, and include largemouth bass (two species), smallmouth bass, and spotted bass (three sub-species). All three species are introduced but have recreational value in California.

Largemouth Bass

Largemouth bass first spawn during their second or third spring at about 7 inches in length. Spawning is limited to freshwater (Moyle 2002). The males begin building nests when the water temperature reaches about 60°F (15.6°C). Spawning takes place from April through June, at temperatures up to 75°F (23.9°C).

Smallmouth Bass

Smallmouth bass reach maturity in their third or fourth spring, at which point they move into shallower water. Spawning begins in May and can continue into June or July (Moyle 2002). Spawning has been observed at temperatures ranging from 13°C to 26°C (55.4°F to 78.8°F), with optimal water temperatures ranging from 16°C to 18°C (60.8°F to 64.4°F) (Wang 2010).

Spotted Bass

Maturity is reached in the second or third year and spawning occurs in freshwater when temperatures reach 15°C to 18°C (59°F to 64.4°F), continuing until temperatures reach 22°C to 23°C (71.6°F to 73.4°F) in early June. Males move to shallow water in March and early April, where they construct nests 40 to 80 cm (31.5 inches) in diameter, generally in shallow areas less than or equal to 6 m deep (University of California, Agriculture and Natural Resources 2019b; Wang 2010).

O.7.22.2 Sacramento River

Spawning

Spawning occurs in freshwater for all three taxa. This means all spawning occurs upstream of the brackish estuary. See details in Section O.4.22.1 above for spawning timing for each species.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 4 compared to the No Action Alternative CalSim 3 simulated mean monthly flows at Keswick Dam, Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤ 4%) increases and/or decreases are March through July; this suggest largemouth, smallmouth, and spotted bass spawning habitat will remain similar to the No Action Alternative (Table O-266, through Table O-269).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 323 for Butte City. Full results of the analysis assessing the percent of months with water temperature outside the 55°F to 70°F optimal range for smallmouth bass spawning during May through July are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 325 for Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 331 for Butte City.

Results for the three analyses are summarized in Table O-151. Table O-151, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-151). For the 55°F to 70°F optimal range for smallmouth bass spawning, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Hamilton City. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Butte City. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on black bass spawning in the Sacramento River.

Summary

Overall, Alternative 4 compared to the No Action Alternative for CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will generally remain similar for largemouth, smallmouth, and spotted bass. The optimal water temperature range modeling estimates indicate neither beneficial nor adverse impacts for largemouth and spotted bass under Alternative 4 compared to the No Action Alternative in the Sacramento River. The optimal water temperature range modeling estimates also indicates no beneficial or adverse combinations at Hamilton City for smallmouth bass in the Sacramento River. Overall, these results suggest that there would be negligible flow impacts on largemouth, smallmouth, spotted bass spawning habitat; water temperature-related impacts on spawning and egg incubation of largemouth, smallmouth and spotted bass would be negligible in the Sacramento River under Alternative 4.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters and may be found from the tributaries of the Sacramento to the brackish estuary. As all three taxa require large quantities of food, they are likely to be more concentrated in areas with plentiful food and instream cover.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 4 compared to the No Action Alternative CalSim 3 simulated mean monthly flows at Keswick Dam, Red Bluff Diversion Dam, Wilkins Slough, and Hamilton City indicate that minor (≤ 4%) increases and/or decreases are most months; this suggest habitat will remain similar to the No Action Alternative (Table O-266, through Table O-269).

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 324 at Butte City. Full results of the analysis assessing the percent of months with water temperature above the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 327 for the Sacramento River at Hamilton. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F

optimal range for non-spawning adult smallmouth bass growth year-round are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 320 for the Sacramento River at Hamilton City. Full results of the analysis assessing the percent of months with water temperature outside the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass during June through August are presented in Attachment L.1, *Sacramento River Water Temperature Analysis*, Table 332 for the Sacramento River at Butte City.

Results for the four analyses are summarized in Table O-152. Table O-152, as described in Section O.4.8.1, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 77°F to 86°F optimal range for non-spawning adult largemouth bass growth, there were no month-water year type combinations (0% of total combinations during the period) with either favorable or unfavorable results at Butte City (Table O-152). For the 66°F lower end of observed summer-time range for non-spawning adult smallmouth bass, there was one month-water year type combinations (6.7%) with favorable results and one combination (6.7%) with unfavorable results at Hamilton City. For the 77°F to 80°F optimal range for non-spawning adult smallmouth bass growth, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Hamilton City. For the 75°F to 87°F preferred summer-time range for non-spawning adult spotted bass, there were no month-water year type combinations (0%) with either favorable or unfavorable results at Butte City. These results suggest that there would be negligible water temperature-related effects of Alternative 4 on black bass non-spawning adults in the Sacramento River.

<u>Summary</u>

Overall, Alternative 4 compared to the No Action Alternative for CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will generally remain similar with some slight adverse impacts on largemouth, smallmouth, spotted bass. The optimal summer water temperature range modeling estimates indicate neither beneficial nor adverse conditions on black basses compared to the No Action Alternative at Butte and Hamilton cities in the Sacramento River. Overall, these results suggest that there would be minor to adverse and beneficial impacts from flow on largemouth, smallmouth, and spotted bass; no water temperature-related impacts on largemouth and spotted bass adults; and negligible water temperature-related impacts on smallmouth bass are expected in the Sacramento River under Alternative 4.

O.7.22.3 Lower American River

Spawning

Spawning for all three taxa occurs in cooler, shallow waters with flow. See details in Section O.4.22.1 above for spawning timing for each species.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam and in the lower American River at H Street indicate that minor (≤ 2%) increases or decreases are estimated March through July (Table O-277 and Table O-278). These results suggest largemouth, smallmouth, and spotted bass spawning habitat will remain similar under Alternative 4 compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 105 for Hazel Avenue and Table 106 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 55°F to 70°F optimal range for smallmouth bass spawning during May through July are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 109 for Hazel Avenue and Table 110 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 115 for Hazel Avenue and Table 116 for Watt Avenue.

Results for the three analyses are summarized in Table O-153. Table O-153, as described in Section O.4.22.2,reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue(Table O-153). There were zero month-water year type combinations with unfavorable results at both Hazel Avenue and Watt Avenue. For the 55°F to 70°F optimal range for smallmouth bass spawning, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were zero and two month-water year type combinations (0.0% and 13.3%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue, respectively. For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were two and zero month-water year type combinations (13.3% and 0.0%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that there would be positive and negative effects of Alternative 4 on black bass spawning in the lower American River.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests negligible impacts on largemouth, smallmouth, and spotting bass spawning habitat

extent. The water temperature modeling for black basses indicates beneficial and adverse impacts from Alternative 4.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters. However, they require large quantities of food; they are likely to remain in slower moving waters of the stream or move vertically within the lake to accommodate preferences.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows below Nimbus Dam and in the lower American River at H Street indicate that minor (≤ 7%) increase and/or decrease is estimated nearly all months in a given year (Table O-277 and Table O-278). These results suggest largemouth, smallmouth, and spotted bass habitat will remain similar nearly all months of the year under Alternative 4 compared to the No Action Alternative.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for growth for largemouth bass during April through June are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 107 for Hazel Avenue and Table 108 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 111 for Hazel Avenue and Table 112 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for growth in smallmouth bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 113 for Hazel Avenue and 114 for Watt Avenue. Full results of the analysis assessing the percent of months with water temperature above the 75°F to 87°F preferred summer-time range for spotted bass during June through August are presented in Attachment M.2, *American River Water Temperature Analysis*, Table 117 for Hazel Avenue and Table 118 for Watt Avenue.

Results for the four analyses are summarized in Table O-154. Table O-154, as described in Section O.4.22.3,reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue (Table O-154). There were also zero month-water year type combinations (0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there was one month-water year type combinations (6.7%) with favorable results at both Hazel Avenue and Watt Avenue. There were two and one month-water year type combinations (13.3% and 6.7%, respectively) with unfavorable results at Hazel Avenue and Watt Avenue,

respectively. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were zero month-water year type combinations (0.0%) with favorable results at both Hazel Avenue and Watt Avenue. There were also zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue. For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero and two month-water year type combinations (0.0% and 13.3%, respectively) with favorable results at Hazel Avenue and Watt Avenue, respectively. There were zero month-water year type combinations (0.0%) with unfavorable results at both Hazel Avenue and Watt Avenue.

These results suggest that there would be beneficial and negative effects of Alternative 4 on black bass non-spawning adults in the lower American River.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests spawning habitat extent will generally remain similar with some slight to moderate beneficial and adverse impacts. The water temperature modeling for black basses indicates beneficial and adverse impacts from Alternative 4.

O.7.22.4 Stanislaus River

Spawning

Spawning for all three taxa occurs in cooler, shallow waters with flow. See details in Section O.4.22.1 above for spawning timing for each species.

Potential Changes to Largemouth and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows show minor (≤ 1%) increases and minor (≤ 2%) to slight (8%) decreases in flow in March through April at Goodwin Dam and mouth of the Stanislaus River (Table O-279 and Table O-280). At Goodwin Dam, a slight (≤ 8%) decrease is expected April and a slight increase (≤ 10%) in July and August. At the mouth, a slight (7%) increase is generally expected in August. At the mouth of the Stanislaus River, all increases and decreases are expected to be minor (up to 3% decrease and up to 7% increase). These results suggest averaged flows may be anticipated to have generally negligible effects on largemouth, smallmouth, and spotted bass spawning habitat.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 52.7°F to 84°F observed range for largemouth bass spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 78 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 58.1°F to 73.4°F observed range for spotted bass spawning during April through June are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 82 for Orange Blossom Bridge.

Results for the two analyses are summarized in Table O-155. Table O-155, as described in Section O.4.22.4, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 52.7°F to 84.2°F observed range for largemouth bass spawning, there was one month-water year type combinations (6.7%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge (Table O-155). For the 58.1°F to 73.4°F observed range for spotted bass spawning, there were two month-water year type combination (13.3%) with favorable results and zero month-water year type combinations (0.0%) with unfavorable results at Orange Blossom Bridge.

These results suggest that there would be positive effects of Alternative 4 on spawning black basses spawning in the Stanislaus River.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests flows may have generally negligible impacts on largemouth, smallmouth, and spotted bass spawning habitat. The optimal water temperature range modeling estimates indicate one (6.7%) month-water year type combinations with adverse conditions for largemouth bass. The optimal water temperature range modeling estimates indicate 1 (6.7%) month-water year type combinations with adverse and beneficial conditions for spotted bass. Overall, these results suggest generally negligible flow impacts on largemouth, smallmouth, and spotted bass spawning habitat; water temperature-related impacts on largemouth and spotted bass spawning are slightly adverse under Alternative 4.

Non-Spawning Adult

Non-spawning adults are generally more tolerant of various water quality parameters. However, they require large quantities of food; they are likely to remain in slower moving waters of the stream or move vertically within the reservoirs to accommodate preferences.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flow Analysis

Alternative 4 compared to the No Action Alternative CalSim 3 mean monthly flows show minor (≤ 1%) to slight (≤ 10%) increases in flow and minor (≤1%) to slight (8%) decreases in flow at Goodwin Dam and mouth of the Stanislaus River (Table O-279 and Table O-280). At Goodwin Dam, slight (≤ 10%) increases are generally expected in February, July, August, and December and a slight (8%) decrease generally April. At the mouth, a slight (7%) increase is generally expected in August. These results suggest averaged flows may be anticipated to have generally beneficial effects on largemouth, smallmouth, and spotted bass.

Water Temperature Analysis

Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 86°F optimal range for growth for largemouth bass during year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 79 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass during June through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 80 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature outside the 77°F to 80°F optimal range for growth in smallmouth bass during year-round are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 81 for Orange Blossom Bridge. Full results of the analysis assessing the percent of months with water temperature above the 75°F to 87°F preferred summer-time range for spotted bass during June through August are presented in Attachment N.1, *Stanislaus River Water Temperature Analysis*, Table 83 for Orange Blossom Bridge.

Results for the four analyses are summarized in Table O-156. Table O-156, as described in Section O.4.22.3, reports the percent of month-water year type combinations in which the percent difference between an alternative and the No Action Alternative in either exceedance above the index value or occurrence outside the index range was >10%.

Under Alternative 4 for the 77°F to 86°F optimal range for growth for largemouth bass, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Road (Table O-156). For the 66°F water temperature lower end of observed summer-time range of non-spawning adult smallmouth bass, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Road. For the 77°F to 80°F optimal range for growth in smallmouth bass, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Road For the 75°F to 87°F preferred summer-time range for spotted bass, there were zero month-water year type combinations (0.0%) with favorable and unfavorable results at Orange Blossom Road.

These results suggest that Alternative 4 would have negligible effects on black bass non-spawning adults in the Stanislaus River at Orange Blossom Bridge.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow and temperature modeling results had some differences. The differences determined by CalSim 3 modeling suggests flows may have generally beneficial impact on largemouth, smallmouth, and spotted bass. The optimal water temperature range modeling estimates were neither beneficial nor adverse for largemouth, smallmouth, and spotted bass. Overall, these results suggest generally minor beneficial and adverse flow and similar water temperature-related impacts on black bass species in the Stanislaus River under Alternative 4 compared to the No Action Alternative.

O.7.22.5 San Joaquin River

Spawning occurs in freshwater for all three taxa. This means all spawning occurs upstream of the brackish estuary. Non-spawning adults are generally more tolerant of various water quality

parameters and may be found from the tributaries of the San Joaquin to the brackish estuary. As all three taxa require large quantities of food, they are more likely to be concentrated in areas with plentiful food and instream cover.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

Alternative 4 compared to the No Action Alternative CalSim 3 modeling results show minor (≤ 5%) increases and decreases in flow are estimated nearly all months at Vernalis; slight (≤ 6%) to moderate (≤ 22%) flow increases are anticipated generally in June through September of critically dry water years (Table O-281). The greatest increases are expected on average in July through August (22%) of critically dry water years. These results suggest averaged flows are generally similar, except during critically dry water years when flows would be higher under Alternative 4 compared to the No Action Alternative; this suggests a beneficial effect on largemouth, smallmouth, and spotted bass.

Changes in water temperature from seasonal operations under Alternative 4 compared to the No Action Alternative are likely to have a negligible impact on black basses in the San Joaquin River. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year (Figure O-15).

Summary

Alternative 4, compared to the No Action Alternative CalSim 3 modeling results, are generally similar, except in critically dry water years when flows would be higher under Alternative 4; this suggests beneficial impacts on largemouth, smallmouth, and spotted bass during critically dry water years. Under Alternative 4, HEC-5Q simulated water temperatures in the San Joaquin River at Vernalis are similar to the No Action Alternative throughout the year.

O.7.22.6 Bay-Delta

Non- spawning adults are present year-round predominantly in the brackish water interface where food is abundant. Larvae and juveniles are likely to remain upstream of the brackish water interface, where plant beds and slower waters occur.

Potential Changes to Largemouth, Smallmouth, and Spotted Bass from Seasonal Operations

CalSim 3 Flows

Alternative 4 compared to the No Action Alternative CalSim 3 modeling results show minor (≤ 5%) to substantial (≤ 54%) increases in flow and minor (5%) to slight (≤ 16%) decreases in flow in the Bay-Delta (Tables O.6-9, O.6-10, and O.6-11). At SWP and CVP exports, slight (8%, February) to moderate (25%, May) flow increases and slight (≤ 12%, December) are expected. At the confluence of Old and Middle River in the Delta, slight (16%, February) to substantial (≤ 54%, May) flow increases and slight (≤ 16%, December) are expected. For Delta outflow, a slight (6%) decrease in flow is generally expected in May. These differences suggest flows may have generally beneficial effects on largemouth, smallmouth, and spotted bass.

Summary

Overall, Alternative 4 compared to the No Action Alternative CalSim 3 flow modeling results had some differences. The differences determined by CalSim 3 modeling suggests flows may generally have beneficial impacts on largemouth, smallmouth, and spotted bass, depending on location and month.

Potential Changes to Entrainment of Largemouth Bass

Differences in exports under Alternative 4 compared with the No Action Alternative may have effects on largemouth bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for largemouth bass include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of largemouth bass under Alternative 4 compared to the No Action Alternative at the SWP Banks Pumping Plant was similar or higher and CVP Jones Pumping Plant was similar or lower all water year types (Tables O-157 and O-158). At the SWP Banks Pumping Plant predicted average monthly loss was up to 18% higher on below normal water years; loss was similar all other water years (Table O-157). At CVP Jones Pumping Plant predicted average monthly loss was up to 9% lower on dry and critically dry water years; loss was similar all other water years (Table O-158).

Potential Changes to Entrainment of Smallmouth Bass

Differences in exports under Alternative 4 compared with the No Action Alternative may have effects on smallmouth bass entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for smallmouth bass include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of smallmouth bass of Alternative 4 compared to the No Action Alternative at SWP Banks Pumping Plant was similar all water year types, except in above normal water years when loss would increase and critically dry water year types when no fish are expected; at CVP Jones Pumping Plant loss would be similar on below normal water years and increase in critically dry water years, all other water year types have no anticipated loss (Table O-159 and Table O-160). At the SWP Banks Pumping Plant predicted average monthly loss increased up to 8% in December through February of below normal water years (Table O-159). At the CVP Jones Pumping Plant predicted average monthly loss increased up to 7% in February of critically dry water years (Table O-160). It should be noted that loss of smallmouth bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Potential Changes to Entrainment of Spotted Bass

Salvage Density

Predictions from the salvage density model for spotted bass include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative.

Predicted average monthly loss of spotted bass of Alternative 4 compared to the No Action Alternative at SWP Banks Pumping Plant was similar in below normal water years and no fish are expected all other water year types; at CVP Jones Pumping Plant loss was similar most water year types, except critically dry water years when loss would decrease (Table O-161 and Table O-162). At the CVP Jones Pumping Plant predicted average monthly loss decreased up to 8% in January and August of critically dry water years (Table O-162). Historical loss of spotted bass at both facilities is rare and infrequent; this is a driver of low values of predicted loss.

Summary

Overall, Alternative 4 compared to the No Action Alternative salvage density modeling results had some differences. The salvage density modeling predicted monthly loss under Alternative 4 are generally slightly to largely lower for largemouth bass for nearly all water year types; a few exceptions at SWP Banks Pumping Plant where slight loss increases are expected compared to the No Action Alternative. The salvage density modeling predicted monthly loss under Alternative 4 are generally slightly to substantially lower for smallmouth bass for nearly all water year types; a few exceptions at SWP Banks Pumping Plant where slight loss increases are expected compared to the No Action Alternative. Overall, loss decreases at CVP Jones Pumping Plant and slight loss increases at SWP Banks Pumping Plant from entrainment of largemouth and smallmouth bass, while spotted bass would have both loss increases and decreases at both facilities under Alternative 4.

O.7.23 Starry Flounder

O.7.23.1 Bay-Delta

Adult starry flounder primarily inhabit coastal marine waters (Orcutt 1950; Haertel and Osterberg 1967; Bottom et al. 1984; Hieb and Baxter 1993). Distribution of age-0 juveniles within the San Francisco Estuary and Delta is primarily in Suisun Bay and San Pablo Bay, with lower abundance in the west Delta (Baxter et al. 1999). Starry flounder older than age 1 (age-1+ fish) occur principally in San Pablo Bay, Suisun Bay, and Central Bay (Baxter et al. 1999).

Starry flounder can tolerate a wide range of salinities. In the Sacramento and San Joaquin Rivers, starry flounder have been observed in salinities as low as 0.02–0.06 ppt (i.e., essentially fresh water) (Orcutt 1950). Age-0 and age-1+ starry flounder are a common species in estuarine habitats along the West Coast (see Orcutt 1950; Pearson 1989; Emmett et al. 1991; Baxter et al. 1999; Kimmerer 2002b).

Spawning occurs primarily during the winter months of December and January (Orcutt 1950). By age-two, many starry flounder are nearing reproductive maturity and have migrated to ocean habitats adjacent to their natal estuaries. Adults may move seasonally into shallow coastal waters

to spawn, perhaps in proximity to estuaries to take advantage of estuarine circulation which would advect fertilized eggs near the bottom into nursery areas.

Potential Changes to Starry Flounder from Seasonal Operations

Differences in Delta outflow between March and June due to seasonal operations under Alternative 4 compared with the No Action Alternative may have effects on starry flounder annual abundance in the Bay-Delta region. These possible differences were evaluated using modeled Delta outflow values from CalSim 3 that were then used as input to the relationship between outflow and abundance for the starry flounder.

Delta Outflow vs. Bay-Delta Species Abundance

Predictions from the Delta Outflow model for starry flounder indicated that the overall average abundance index for Alternative 4 would essentially be similar to mean abundance under the No Action Alternative across all water years (-3% to 0%), with considerable overlap in confidence intervals around median values. This would indicate substantial variability between years (Attachment J.6, *Bay-Delta Species Abundance- Delta Outflow Relationships*).

Summary

The Delta Outflow model indicated minimal adverse impacts on mean abundance for the starry flounder across all water year types when comparing Alternative 4 and the No Action Alternative, with a considerable overlap in confidence intervals. This suggests substantial variability between years.

Potential Changes to Entrainment of Starry Flounder

Differences in exports under Alternative 4 compared with the No Action Alternative may have effects on starry flounder entrainment at the Delta Fish Collection Facilities. These possible differences were evaluated using the Salvage Density Model (Attachment I.2, *Salvage Density Model Loss Simulation*).

Salvage Density

Predictions from the salvage density model for starry flounder include mean monthly total exports. Table O-271 shows modeled mean monthly total exports at SWP and CVP. Refer to the table for differences between Alternative 4 and the No Action Alternative. Predicted average monthly loss of starry flounder under Alternative 4 compared to the No Action Alternative at the SWP Banks Pumping Plant increased most water year types, except critically dry water years when loss was similar; at CVP Jones Pumping Plant loss was similar all water year types (Table O-163 and Table O-164). At the SWP Banks Pumping Plant predicted average monthly loss increase ranged from 12% in February through August of below normal water years to 51% in March, April, May, July, August, and November of dry water years (Table O-163). Historical loss of starry flounder at both facilities is infrequent; this is a driver of low values of predicted loss.

Summary

Alternative 4 relative to the No Action Alternative is expected to have a minimal adverse impact on entrainment of starry flounder due to difference in exports. The predicted average monthly loss of starry flounder due to operations at SWP Banks were projected to increase in most water

year types and be similar to the No Action Alternative in critically dry years. At the CVP Jones, loss was similar to the No Action Alternative across all water year types.

O.7.24 Coastal Pelagic Species

O.7.24.1 Potential Changes to Northern Anchovy and Pacific Herring from Seasonal Operations

Northern anchovy and Pacific herring could be subject to operational effects of the Proposed Action as it pertains to Delta outflow and its effect on the salinity field. However, the effects on salinity would be small relative to the salinity tolerance of Coastal Pelagic Species EFH such as Northern Anchovy (Baxter et al. 1999). Kimmerer et al. (2009) showed for Northern Anchovy that neither indices of habitat extent nor indices of abundance were related to X2, an index of Delta outflow and its effects.

Kimmerer (2009) found Pacific herring abundance indices were not associated with flow. However, Pacific herring do utilize the San Francisco Bay Estuary as spawning and rearing habitat (Pak et al. 2023, Grimaldo et al. 2020, Watters et al. 2004). Grimaldo et al. (2020) found Pacific herring larvae presence and abundance was lower in landward regions (e.g. Suisun Bay) during a high outflow year, likely due to either increased advection from high flows or reduced net landward movement via gravitational circulation. Juvenile herring abundance in Suisun Bay in the spring is associated with saltier conditions that allow their range to expand landward (Pak et al. 2023).

O.7.24.2 Potential Changes to Entrainment of Northern Anchovy and Pacific Herring

There are no expected impacts to entrainment of Northern anchovy due to operations since the distribution in the San Francisco Estuary has shifted towards higher salinities (> 20) since the introduction of the invasive clam, *Potamocorbula amurensis* (Kimmerer 2006). Impacts to entrainment of Pacific herring are potentially adverse in drier water year types depending on severity but are likely to be extremely rare. Historical salvage of Pacific herring has only occurred a few times since 2000, primarily in 2014, a critically dry year (during the months of March and April), fish were also salvaged in 2019 and 2020 in much lower numbers (CDFW 2024c).

O.7.25 Southern Oregon/Northern California Coast Coho salmon ESU

O.7.25.1 Trinity River

Spawning and Egg/Alevin Incubation

Most coho salmon spawning in the mainstem Trinity River occurs in November and December between Lewiston Dam and the North Fork Trinity River (Section O.1.2.5.1, *Coho salmon, Southern Oregon/Northern California Coast ESU*). Coho salmon eggs and alevins in the Trinity and Klamath River basins may be present in the gravel from November to mid-May (Leidy and Leidy 1984), so effects of flow and water temperature on coho salmon eggs and alevins may occur during this period.

Potential Changes to Coho Salmon from Seasonal Operations

Under Alternative 4, modeled monthly average flows in the Trinity River below Lewiston Dam in December of wet water years, January of wet water years, and February of above normal water years would be at least 5% greater than the No Action Alternative (Table O-264). These changes would have variable effects on the availability and suitability of spawning and egg/alevin incubation habitat for coho salmon.

In December and January when coho salmon are spawning and eggs/alevins may be incubating in the Trinity River, modeled monthly average flow would increase in December of wet water years from 1,133 cfs under the No Action Alternative to 1,193 cfs under Alternative 4 and in January in wet water years from 1,872 cfs under the No Action Alternative to 1,985 cfs under Alternative 4 (Table O-264). In February when coho salmon eggs/alevins are incubating, modeled monthly average flow in above normal water years would increase in February from 1,194 cfs under the No Action Alternative to 1,393 cfs under Alternative 4.

The increased modeled monthly average flow in December of wet water years may provide variable changes to spawning coho salmon by slightly increasing WUA for spawning adults in the most heavily used spawning reach from Lewiston to Dutch Creek and slightly decreasing WUA for spawning adults in the lesser used downstream reaches (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999; Rupert et al. 2017a, b). In January, the increased monthly average flow in wet water years may increase spawning WUA for coho salmon in lesser-used downstream portions of the Trinity River but is predicted to have little to no change in spawning WUA in the more heavily used reach from Dutch Creek to North Fork Trinity River (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

The effect of the modeled December and January flow increases on spawning suitability in the reach from Lewiston Dam to Dutch Creek is uncertain because WUA for adult salmon in this reach has not been quantified for flows above 800 cfs (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In this reach as in other reaches, WUA is likely to vary spatially with channel confinement and incision (Goodman et al. 2018).

Compared with the No Action Alternative, the December and January flow increases would not result in changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-20 and Figure O-21) and average water temperatures under Alternative 4 would likely remain well below the upper water temperature objective of 56°F to protect spawning coho salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11). In all but the driest water years, average December and January water temperatures from Lewiston Dam to the North Fork Trinity River would likely remain below the 50°F upper suitability limit recommended by Washington State Department of Ecology (WDOE) (2002, as cited in Carter 2005) to support coho salmon incubation and emergence (Asarian et al. 2023).

Compared with the No Action Alternative, the increased monthly average flows in December and January under Alternative 4 would likely have variable effects on the availability and suitability of coho salmon spawning and incubation habitat in the Trinity River, potentially including an increase in the amount of usable habitat in the reaches most heavily used by coho salmon. The potential increase would occur in December in wet water years, which have occurred 28% of the

time over the 100-year simulation period. In the lesser used downstream reaches, there would be a modeled increase in WUA in January of wet water years.

Although WUA for egg/alevin incubation is not available for the Trinity River, the changes in modeled monthly average flows in above normal water years in February under Alternative 4 would be unlikely to change redd hydraulics or redd substrate conditions relative to the No Action Alternative, and no effects on egg/alevin incubation suitability are expected. The modeled February flow increases would result in no change in modeled monthly average water temperature relative to the No Action Alternative (Figure O-17) and water temperature in February under Alternative 4 would remain well below the 50°F upper suitability limit recommended by Washington State Department of Ecology (WDOE) (2002, as cited in Carter 2005) to support coho salmon incubation and emergence (Asarian et al. 2023). Compared with the No Action Alternative, the flow increases in February under Alternative 4 would be unlikely to have substantial impacts on the availability or suitability of coho salmon spawning and egg/alevin incubation habitat.

Compared with the No Action Alternative, the changes in seasonal operations in December, January, and February under Alternative 4 are expected to have minor adverse impacts to benefits on the availability or suitability of coho salmon spawning and egg/alevin incubation habitat.

Juvenile Rearing and Emigration

Naturally spawned juvenile coho salmon in the Trinity River emerge from the gravel and begin rearing in winter and early spring, with the first captures of young-of-year (age-0) coho salmon typically occurring in early March (U.S. Fish and Wildlife Service 2023, unpublished; Yurok Tribe 2023, unpublished). Fry, juvenile, and subyearling coho salmon rearing in the Trinity River strongly prefer areas of slow water velocity and habitat with cover from woody material, overhanging vegetation, and clusters of aquatic vegetation (Hampton 1988, 1997; Chase et al. 2009; Pinnix et al. 2019). During high flows, young coho salmon use floodplains and other off-channel habitats (Chase et al. 2009). Rearing occurs year-round, typically over a period of 12–15 months, and the effects of flow and water temperature on rearing coho salmon therefore occur throughout the year. Most Trinity River coho salmon outmigrate to the ocean as yearling smolts between January and July (Harris et al. 2016; Petros et al. 2015; Petros et al. 2017).

Potential Changes to Coho Salmon from Seasonal Operations

Seasonal operations under Alternative 4 would have spatially and temporally variable effects on the availability and suitability of juvenile rearing and emigration habitat for coho salmon. Compared with the No Action Alternative, substantial differences (greater than 5%) in modeled monthly average flows would occur in some water year types in December, January, and February and are described in detail in the preceding sections and shown in Table O-264. In all other months and water year types there would be little or no difference in modeled monthly average flow between Alternative 4 and the No Action Alternative and no effects on coho salmon would be expected.

Compared with the No Action Alternative, the increased modeled monthly average flow in December of wet water years would have little to no change in WUA for fry and juvenile coho salmon across all reaches of the Trinity River from Lewiston Dam to Weitchpec (U.S. Fish and

Wildlife Service & Hoopa Valley Tribe 1999). In December of wet water years, increased monthly average flow under Alternative 4 would result in a slight increase in fry WUA and a slight decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, little to no change in fry and juvenile WUA in the reach from Dutch Creek to North Fork Trinity River, little to no change in fry WUA and a slight decrease in juvenile WUA in the reach from North Fork Trinity River to South Fork Trinity River, and a slight increase in fry WUA and little to no change in juvenile WUA in the reach from South Fork Trinity River to Weitchpec.

The increased monthly average flows in January in wet water years would result in increases in WUA for fry and juvenile coho salmon from Lewiston Dam to Dutch Creek, no change in fry and juvenile WUA from Dutch Creek to North Fork Trinity River, a slight increase in fry WUA and a slight decrease in juvenile WUA from North Fork Trinity River to South Fork Trinity River, and little to no change in fry and juvenile WUA from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

The effect of flow differences on rearing suitability is likely to vary spatially with channel confinement and incision (Cooper-Hertel et al. 2022). In locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships. These changes in WUA for coho salmon fry and juveniles may have minor, short-term effects on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the 12–15 month rearing period and in some reaches of the Trinity River.

In December of wet water years, January of wet water years, and February of above normal water years, differences in modeled monthly average flows between Alternative 4 and the No Action Alternative would not result in differences in modeled monthly average water temperature in the Trinity River below Lewiston (Figure O-20 and Figure O-21, respectively).. December, January, and February of the aforementioned water year types, modeled monthly average water temperatures at Trinity River below Lewiston Dam under Alternative 4 would remain well below the 59°F water temperature objective for emigrating juvenile coho salmon (smolts) recommended for normal and wetter water year types and the 62.6°F objective in dry and critically dry water years (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999).

Although the water temperature objectives are intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in December, January, and February would remain below both objectives under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating coho salmon under Alternative 4 relative to the No Action Alternative. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 4 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives in portions of the coho salmon juvenile rearing and emigration period at downstream locations in some water year types under Alternative 4, water temperatures and the potential effects on coho salmon would not differ from the No Action Alternative.

Compared with the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 4 would cause only negligible changes in factors affecting the availability or suitability of coho salmon rearing and emigration habitat and substantial impacts on coho salmon would be unlikely.

Adult Upstream Migration and Holding

From August to January, coho salmon return from the ocean through the Klamath River Estuary to the Trinity River, moving upstream toward spawning habitat. Based on recent weir counts, the date of peak abundance of upstream-migrating coho salmon in the Trinity River ranges from late September to mid-November (Kier et al. 2018, 2019, 2020, 2021, 2022). After completing their upstream migration, mature coho salmon may hold for days, weeks, or sometimes months before spawning. Because most spawning occurs in November and December, the effects of flow and water temperature on migrating and holding coho salmon would primarily occur from August through December.

Potential Changes to Coho Salmon from Seasonal Operations

During the coho salmon upstream migration and holding period there would be no differences in modeled monthly average flow between Alternative 4 and the No Action Alternative in August, September, October, or November and substantial (greater than 5%) differences in December and January. Differences would vary by month and water year type, and are described in detail in the preceding sections and shown in Table O-264. These differences may result in minor, short-term changes in habitat conditions but modeled monthly average flows from August through December when adult coho salmon are migrating and holding would be equal to or greater than 300 cfs in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and holding habitat to support pre-spawning coho salmon.

Modeled monthly average flows in August and September, when adult coho salmon begin migrating upstream from the ocean and water temperatures are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 4 as under the No Action Alternative (Table O-264). Under both alternatives, modeled August and September flows of 760 cfs in wet water years and 863 cfs in all other water year types would maintain suitable water temperatures for adult upstream migration (60°F in August and early September and 56°F in late September; Table O-11) based on modeled monthly average water temperatures in the Trinity River at Lewiston Dam (Figure O-17). Although downstream warming during August and September could result in unsuitable water temperatures for migrating coho salmon at some locations, the likelihood of this occurring would be the same under Alternative 4 as under the No Action Alternative due to the identical flows.

During the late September to mid-November peak adult migration period, the modeled monthly average flows under Alternative 4 would be the same as the No Action Alternative except for a reduction of 5 cfs in November in above normal water years (Table O-264), which is essentially the same. In December and January, a substantial flow difference (greater than 5%) between the two alternatives would be a modeled increase of 60 cfs in December in wet water years from 1,133 cfs under the No Action Alternative to 1,193 cfs under Alternative 4 and in January in wet water years would be a modeled increase of 114 cfs under the No Action Alternative from 1,872 cfs to 1,985 cfs under Alternative 4. The December flow difference would not have measurable

impacts on modeled monthly average water temperature at Lewiston Dam in the respective water year types (Figure O-20 and Figure O-21) and there would be no impacts on water temperature suitability for coho salmon migration and holding relative to the No Action Alternative. Compared with the No Action Alternative, the differences in modeled monthly average flows and associated differences in modeled monthly average water temperature under Alternative 4 would cause only negligible changes in factors affecting the availability or suitability of coho salmon upstream migration and holding habitat and substantial impacts on coho salmon would be unlikely.

O.7.26 Upper Klamath-Trinity River Spring-run Chinook Salmon ESU

O.7.26.1 Trinity River

Spawning and Egg/Alevin Incubation

Most spring-run Chinook salmon in the Trinity River spawn from late September to mid-November, with a peak in October (Gough et al. 2021a,b). At optimal intragravel temperatures (41–55°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another four to six weeks (Healey 1991, Moyle 2002). In the Trinity River, spring-run Chinook salmon incubation and emergence typically occurs through February (Leidy and Leidy 1984). The effects of flow and water temperature on spring-run Chinook salmon spawning and egg/alevin incubation may therefore occur from approximately mid-September through February.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Under Alternative 4, modeled monthly average flows in the Trinity River below Lewiston Dam in December of wet water years, January of wet water years, and February of above normal water years would be at least 5% greater than the No Action Alternative (Table O-264). The monthly flow differences would have minor effects on the availability or suitability of spawning and egg/alevin incubation habitat for spring-run Chinook salmon relative to the No Action Alternative. Under Alternative 4, like the No Action Alternative, the variable flow regime is expected to maintain spawning habitat quality through periodic scour and redeposition of spawning gravel, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

Modeled monthly average flow in December of wet water years would increase from 1,133 cfs under the No Action Alternative to 1,193 cfs under Alternative 4. Some adult spring-run Chinook salmon may still be spawning and eggs/alevins may be incubating during December. The December flow increase may benefit spawning spring-run Chinook salmon by increasing WUA for spawning adults in the downstream portion of the primary spawning reach from Dutch Creek to North Fork Trinity River compared with the No Action Alternative (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999; Rupert et al. 2017a, b). The WUA results for spawning spring-run Chinook salmon in the upstream portion of the primary spawning reach from Lewiston Dam to Dutch Creek do not include flows greater than 800 cfs so no WUA evaluation is possible for this segment of the river. Comparative effects on spawning suitability would vary in reaches downstream of North Fork Trinity River, with a decrease in spawning WUA from North Fork Trinity River to South Fork Trinity River and no change in spawning WUA from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe

1999). The effects of flow changes on spawning suitability are likely to vary spatially with channel confinement and incision (Goodman et al. 2018), with the modeled average flow increase in December of wet water years potentially resulting in greater spawning WUA in unconfined channels than in confined channels. Although WUA for egg/alevin incubation is not available for the Trinity River, the modeled flow increase under Alternative 4 in December of wet water years is unlikely to cause changes in redd hydraulics, sediment, or other conditions relative to the No Action Alternative, and no effects on egg/alevin incubation suitability are expected.

In January of wet water years, modeled monthly average flow would increase from 1,872 cfs under the No Action Alternative to 1,985 cfs under Alternative 4 (Table O-264). In February of above normal water years, modeled monthly average flow would increase from 1,194 cfs under the No Action Alternative to 1,393 cfs under Alternative 4. Although WUA for egg/alevin incubation is not available for the Trinity River, the January and February flow increases are not expected to change redd hydraulics, sediment, or other conditions that may affect incubation suitability.

The modeled December flow increase would not result in measurable changes in modeled average water temperature in the Trinity River below Lewiston Dam (Figure O-17) and average water temperatures under Alternative 4 would likely remain well below the upper water temperature objective of 56°F to protect spawning spring-run Chinook salmon in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11). Similarly, the January and February flow increases would not result in measurable changes in modeled average water temperature in the Trinity River below Lewiston Dam (Figure O.3-1) and average water temperatures under Alternative 4 would remain below the 50°F (10°C) upper optimum limit recommended by USEPA (2001, as cited in Carter 2005) from Lewiston Dam to North Fork Trinity River in all water year types to support spring-run Chinook salmon incubation and emergence (Asarian et al. 2023).

Overall, the impacts in the reaches most heavily used by spawning and incubating spring-run Chinook salmon would likely be negligible or slightly beneficial under Alternative 4 relative to the No Action Alternative, with spatial variability related to the effects of channel geometry on habitat suitability.

Juvenile Rearing and Emigration

In the Trinity River, spring-run Chinook salmon fry emerge from the gravel beginning in December and most emergence is complete by the end of February (Leidy and Leidy 1984). Fry and juvenile Chinook salmon rearing in the Trinity River preferentially use areas of relatively slow water velocity and habitat with woody material, undercut banks, and other complex cover (Hampton 1988, Pinnix et al. 2019). Naturally spawned juvenile spring-run Chinook salmon typically outmigrate as sub-yearlings from the Trinity River and occasionally as yearlings. Hatchery releases of spring-run Chinook salmon also include mostly sub-yearlings and some yearling releases in spring and fall, respectively. Peak outmigration of natural and hatchery origin juveniles occurs in May, June, and July based on monitoring in the lower Trinity River near the town of Willow Creek (Harris et al. 2016; Petros et al. 2017). The effects of flow and water temperature on rearing and emigrating spring-run Chinook salmon may therefore occur from December through July.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Under Alternative 4, modeled monthly average flows in the Trinity River below Lewiston Dam in December of wet water years, January of wet water years, and February of above normal water years would be at least 5% greater than the No Action Alternative (Table O-264). The December, January, and February differences may have spatially variable effects on the availability and suitability of juvenile rearing and emigration habitat for spring-run Chinook salmon.

The increase in modeled monthly average flow in December in wet water years from 1,133 cfs under the No Action Alternative to 1,193 cfs under Alternative 4 would result in an increase in fry WUA and a decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, a decrease in both fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and an increase in fry WUA and a decrease in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The modeled monthly average flow increase in January of wet water years from 1,872 cfs under the No Action Alternative to 1,985 cfs under Alternative 4 would result in an increase in fry and juvenile WUA in the reach from Lewiston Dam to Dutch Creek, a decrease in fry and juvenile WUA in the reach from Dutch Creek to North Fork Trinity River, an increase in fry WUA and a decrease in juvenile WUA in the reach from North Fork Trinity River to South Fork Trinity River, and an increase in fry WUA and no change in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the modeled monthly average flow increase from 1,194 cfs under the No Action Alternative to 1,393 cfs under Alternative 4 would result in an increase in fry WUA and a decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, a decrease in both fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and a decrease in fry WUA and no change in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Where the channel is naturally unconfined and not overly incised and in locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships and rearing WUA in some restored areas may exhibit a stronger positive relationship to flow up to approximately 3,500 cfs (Cooper-Hertel et al. 2022). Consequently, spring-run Chinook salmon WUA in all reaches is likely to vary spatially with channel confinement and incision and WUA in restored areas may be greater than described in U.S. Fish and Wildlife Service and Hoopa Valley Tribe (1999). See Section O.4.24.1.1 for additional details. The potential changes in WUA for spring-run Chinook salmon fry and juveniles may have minor, short-term effects on the ability of these life stages to access cover and preferred habitat that would occur only in a few months of the eight-month rearing and emigration period and in some reaches of the Trinity River and in certain water years.

In December and January of wet water years and February of above normal water years, differences in modeled monthly average flows between Alternative 4 and the No Action Alternative would not result in measurable changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figures O-19 and O-17). In these months and water year types, modeled monthly average water temperatures at Trinity River below Lewiston Dam under Alternative 4 would remain well below the 62.6°F water temperature

objective for emigrating juvenile spring-run Chinook salmon recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that water temperatures in December, January, and February would remain below the objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating spring-run Chinook salmon under Alternative 4 relative to the No Action Alternative.

Compared with the No Action Alternative, seasonal operations under Alternative 4 would likely have negligible impacts on the availability and suitability of spring-run Chinook salmon juvenile rearing and emigration habitat in the Trinity River. The impacts would vary spatially due to the effects of channel geometry on habitat suitability.

Adult Upstream Migration and Holding

Adult spring-run Chinook salmon typically enter the Trinity River from April through September. By the end of July, most fish have arrived at the primary spawning reach, which extends from Lewiston Dam downstream to the confluence with the North Fork Trinity River. After entering freshwater, spring-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically begins in late September (Leidy and Leidy 1984; Gough et al. 2019, 2021a,b). The effects of flow and water temperature on migrating and holding spring-run Chinook salmon adults may therefore occur from April through September.

Potential Changes to Spring-run Chinook Salmon from Seasonal Operations

Under Alternative 4, seasonal operations in the Trinity River are expected to provide similar habitat conditions for spring-run Chinook salmon upstream migration and holding to the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish including Chinook salmon. During the April–September spring-run Chinook salmon upstream migration and holding period there would be minor (less than 5%) differences in modeled monthly average flow between the two alternatives in April and no differences in May through September (Table O-264). The minor differences in April are not expected to result in changes in habitat suitability for migrating and holding spring-run Chinook salmon. During the entirety of the adult upstream migration and holding period, monthly average flows would be approximately 500 cfs or greater in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and holding habitat to support pre-spawning spring-run Chinook salmon.

Modeled monthly average flows in July, August and September, when adult spring-run Chinook salmon may be holding and water temperatures are typically at or near seasonal highs (Asarian et al. 2023), would be the same under Alternative 4 as under the No Action Alternative (Table O-264). Under both alternatives, July–September flows would maintain suitable water temperatures for adult upstream migration (60°F from July 1 to September 14 and 56°F from September 15 to September 30 at Douglas City [RM 93.7]; Table O-11) (Asarian et al. 2023). Although downstream warming during the warmest months and driest water year types could result in unsuitable water temperatures for migrating spring-run Chinook salmon at some locations (Buxton 2023), the likelihood of this occurring would be the same under Alternative 4 as under the No Action Alternative because May–September flows would be the same under both

alternatives. Under Alternative 4, suitability for adult spring-run Chinook salmon upstream migration and holding would be the same as under the No Action Alternative.

O.7.27 Upper Klamath-Trinity River Fall-run Chinook Salmon ESU

O.7.27.1 Trinity River

Spawning and Egg/Alevin Incubation

Most fall-run Chinook salmon in the Trinity River spawn from late October to December, with a peak in spawning occurring in November (Myers et al. 1998, Leidy and Leidy 1984). Optimal spawning temperatures are reported to be less than 55.4°F (Moyle 2002). At optimal intragravel temperatures (43–54°F) the incubation period lasts 40–60 days and alevins may remain in the gravel for another 4–6 weeks (Moyle 2002). In the Trinity River, fall-run Chinook salmon incubation and emergence typically occurs from December through late February (Leidy and Leidy 1984). The effects of flow and water temperature on fall-run Chinook salmon spawning and egg/alevin incubation may therefore occur from approximately mid-October through February.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Under Alternative 4, modeled monthly average flows in the Trinity River below Lewiston Dam in December of wet water years, January of wet water years, and February of above normal water years would be at least 5% greater than the No Action Alternative (Table O-264). The December, January, and February flow increases would occur during the egg/alevin incubation period. The monthly flow differences would have minor effects on the suitability of egg/alevin incubation habitat for fall-run Chinook salmon relative to the No Action Alternative. Under Alternative 4, like the No Action Alternative, the variable flow regime is expected to periodically scour and redeposit spawning gravel, which is expected to improve incubation conditions and egg-to-emergence survival by reducing fine sediment.

Modeled monthly average flow in the Trinity River below Lewiston Dam would increase in December of wet water years from 1,133 cfs under the No Action Alternative to 1,193 cfs under Alternative 4 and in January of wet water years from 1,872 cfs under the No Action Alternative to 1,985 cfs under Alternative 4 (Table O-264). In February of above normal water years, modeled monthly average flow would increase from 1,194 cfs under the No Action Alternative to 1,393 cfs under Alternative 4. Although WUA for egg/alevin incubation is not available for the Trinity River, these modeled flow increases are unlikely to cause changes in redd hydraulics, sediment, or other conditions relative to the No Action Alternative, and no changes in egg/alevin incubation suitability are expected.

The modeled December, January, and February flow increases would not result in measurable changes in modeled average water temperature in the Trinity River below Lewiston Dam (Figure O.-17) and average water temperatures under Alternative 4 would remain below the 50°F (10°C) upper optimum limit recommended by USEPA (2001, as cited in Carter 2005) from Lewiston Dam to North Fork Trinity River in all water year types to support fall-run Chinook salmon incubation and emergence (Asarian et al. 2023).

Overall, the impacts in the reaches most heavily used for spawning and incubation by fall-run Chinook salmon would likely be negligible under Alternative 4 relative to the No Action Alternative.

Juvenile Rearing and Emigration

In the Trinity River, fall-run Chinook salmon fry emerge from the gravel beginning in December and most emergence is complete by mid-April. Natural juvenile fall-run Chinook salmon primarily outmigrate as sub-yearlings from the Trinity River. Hatchery releases of fall-run Chinook salmon also include mostly smolts released primarily in late spring and fall. Peak outmigration occurs in March, April, and May but can extend to July based on monitoring in the lower Trinity River near the town of Willow Creek (Moyle 2002, Chesney and Yokel 2003). The effects of flow and water temperature on rearing and emigrating fall-run Chinook salmon may therefore occur primarily from December through July.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Under Alternative 4, modeled monthly average flows in the Trinity River below Lewiston Dam would be at least 5% greater than the No Action Alternative in December of wet water years, January of wet water years, and February of above normal water years (Table O-264). The modeled December, January, and February flow increases may have spatially variable effects on the availability and suitability of juvenile rearing and emigration habitat for fall-run Chinook salmon. The increase in modeled monthly average flow in December of wet water years from 1,133 cfs under the No Action Alternative to 1,193 cfs under Alternative 4 would result in an increase in fry WUA and a decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, a decrease in both fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and an increase in fry WUA and a decrease in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The modeled monthly average flow increase in January of wet water years from 1,872 cfs under the No Action Alternative to 1,985 cfs under Alternative 4 would result in an increase in fry and juvenile WUA in the reach from Lewiston Dam to Dutch Creek, a decrease in fry and juvenile WUA in the reach from Dutch Creek to North Fork Trinity River, an increase in fry WUA and a decrease in juvenile WUA in the reach from North Fork Trinity River to South Fork Trinity River, and an increase in fry WUA and no change in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the modeled monthly average flow increase from 1,194 cfs under the No Action Alternative to 1,393 cfs under Alternative 4 would result in an increase in fry WUA and a decrease in juvenile WUA in the reach from Lewiston Dam to Dutch Creek, a decrease in both fry and juvenile WUA in the reaches from Dutch Creek to North Fork Trinity River and North Fork Trinity River to South Fork Trinity River, and a decrease in fry WUA and no change in juvenile WUA in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Where the channel is naturally unconfined and not overly incised and in locations where channel restoration has reduced anthropogenic confinement and incision, the 1999 WUA estimates may not accurately represent contemporary flow-habitat relationships and rearing WUA in some restored areas may exhibit a stronger positive relationship to flow up to approximately 3,500 cfs (Cooper-Hertel et al. 2022). Consequently, fall-run Chinook salmon WUA in all reaches is likely to vary spatially with channel confinement and incision and in

WUA in restored areas may be greater than described in U.S. Fish and Wildlife Service and Hoopa Valley Tribe (1999) at all but the lowest flows. See Section O.4.24.1.1 for additional details. The potential changes in WUA for fall-run Chinook salmon fry and juveniles may have minor, short-term effects on the ability of these life stages to access cover and preferred habitat that would occur only in a few months during the rearing and emigration period and in some reaches of the Trinity River and certain water years.

In December and January of wet water years and February of above normal water years, differences in modeled monthly average flows between Alternative 4 and the No Action Alternative would not result in measurable changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figures O-19 and O-17). In these months and water year types, modeled monthly average water temperatures at Trinity River below Lewiston Dam under Alternative 4 would remain well below the 62.6°F water temperature objective for emigrating juvenile fall-run Chinook salmon recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the objectives are intended to be measured at Weitchpec and applicable prior to July 9, historical data and model results suggest that water temperatures in December, January, and February would remain below the objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating fall-run Chinook salmon under Alternative 4 relative to the No Action Alternative.

Compared with the No Action Alternative, seasonal operations under Alternative 4 would likely have negligible impacts on the availability and suitability of fall-run Chinook salmon juvenile rearing and emigration habitat in the Trinity River. The impacts would vary spatially due to the impacts of channel geometry on habitat suitability.

Adult Upstream Migration and Holding

Adult fall-run Chinook salmon typically enter the Trinity River from September through October (Moyle et al. 2015). Two to four weeks after river entry, adults have made it to the primary spawning reach which extends from Lewiston Dam downstream to the confluence of the North Fork Trinity River. After entering freshwater, fall-run Chinook salmon remain in deep pools until the onset of the spawning season, which typically ranges from the third week of September through November, peaking in October (Chesney and Knechtle 2012). The effects of flow and water temperature on migrating and pre-spawning fall-run Chinook salmon adults may therefore occur from August through November.

Potential Changes to Fall-run Chinook Salmon from Seasonal Operations

Under Alternative 4, seasonal operations in the Trinity River are expected to provide similar habitat conditions for fall-run Chinook salmon upstream migration and holding to the No Action Alternative. Like the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would be managed to maintain suitable habitat conditions for anadromous fish including Chinook salmon. During the August through November fall-run Chinook salmon upstream migration and pre-spawning period there would be no differences in modeled monthly average flow from August through October, and less than 5% reduction in flow in November of above normal water years (Table O-264). The modeled average flow difference in November would be negligible (5 cfs) and is not expected to result in changes in habitat suitability for migrating and holding fall-run Chinook salmon. During the entirety of the adult upstream

migration and holding period, modeled monthly average flows would be approximately 300 cfs or greater in all water year types, and substantially greater in some months and water years, to provide suitable depth for upstream passage as well as access to cover and holding habitat to support pre-spawning fall-run Chinook salmon.

Modeled monthly average flows in August, September, and October during the adult fall-run Chinook salmon migration and pre-spawning period would be the same under Alternative 4 as under the No Action Alternative (Table O-264). Under both alternatives, modeled average August and September flows would be approximately 760 cfs or greater in all water year types and substantially greater in wetter years. Modeled average flows in October would be 373 cfs in all water year types. Under both alternatives, September through October flows would maintain suitable water temperatures for adult upstream migration (60°F to 56°F in September, and <56°F from August through October at Douglas City [RM 93.7]; Table O-11) (Asarian et al. 2023). Under Alternative 4, suitability for adult fall-run Chinook salmon upstream migration and pre-spawning would be the same as the No Action Alternative.

O.7.28 Klamath Mountains Province Steelhead DPS

O.7.28.1 Trinity River

Monthly average flows in the Trinity River below Lewiston Dam would generally be similar under Alternative 4 to flows under the No Action Alternative. Differences in modeled monthly average flows between Alternative 4 and the No Action Alternative would occur in November through April of some water year types, with most differences less than 5%. Like the No Action Alternative, seasonal flow releases under Alternative 4 are expected to maintain a low risk of disease outbreaks for steelhead by maintaining minimum flows and relatively cool water temperatures.

Spawning and Egg/Alevin Incubation

Spawning across run types in the Trinity River may occur anytime from December through May so effects of flow and water temperature on spawning may occur during this period.

Steelhead eggs and alevins across run types in the Trinity River may be present in the gravel from December through June, so effects of flow and water temperature on steelhead eggs and alevins may occur during this period.

Potential Changes to Steelhead from Seasonal Operations

Under Alternative 4, modeled monthly average flows in the Trinity River below Lewiston Dam in December of wet water years, January of wet water years, and February of above normal water years would be at least 5% greater than the No Action Alternative (Table O-264). These changes would have variable effects on the availability and suitability of spawning and egg/alevin incubation habitat for steelhead. In March and April, modeled monthly average flows under Alternative 4 would be largely the same as the No Action Alternative, with minor (less than 5%) differences in March in a few water year types and negligible differences in April in a few water year types. Modeled monthly average flows in May under Alternative 4 would be the same as the No Action Alternative.

Modeled monthly average flow in the Trinity River below Lewiston Dam would increase in December of wet water years from 1,133 cfs under the No Action Alternative to 1,193 cfs under Alternative 4 and in January of wet water years from 1,872 cfs under the No Action Alternative to 1,985 cfs under Alternative 4 (Table O-264). In February of above normal water years, modeled monthly average flow would increase from 1,194 cfs under the No Action Alternative to 1,393 cfs under Alternative 4.

The increased modeled monthly average flow in December of wet water years would result in slightly increased WUA for spawning adults from Dutch Creek to North Fork Trinity River and little to no change from North Fork Trinity River to South Fork Trinity River and South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). The effect of the modeled December flow increase on spawning suitability in the reach from Lewiston Dam to Dutch Creek is uncertain because WUA in this reach has not been quantified for flows above 800 cfs (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In this reach as in other reaches, WUA for spawning is likely to vary spatially with channel confinement and incision (Goodman et al. 2018). Compared with the No Action Alternative, the December flow increase would not result in measurable changes in modeled monthly average water temperature in the Trinity River below Lewiston Dam (Figure O-20 and Figure O-21) and average water temperatures under Alternative 4 would likely remain well below the upper water temperature objective of 56°F to protect spawning salmonids in the reach from Lewiston Dam to the North Fork Trinity River (Table O-11). Compared with the No Action Alternative, the increased monthly average flows in December under Alternative 4 would likely have a negligible or slightly beneficial effect on the availability and suitability of steelhead spawning and incubation habitat in the Trinity River.

The modeled flow increases in January of wet water years would result in little to no change in WUA for steelhead spawning in the reaches from Dutch Creek to South Fork Trinity River and a small increase in the reach from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). In February of above normal water years, the modeled flow increase would result in a negligible decrease in WUA for steelhead spawning from Dutch Creek to North Fork Trinity River, a decrease from North Fork Trinity River to South Fork Trinity River, and an increase from South Fork Trinity River to Weitchpec. The modeled December, January, and February flow increases would not result in measurable changes in modeled monthly average water temperatures relative to the No Action Alternative (Figure O-17) and water temperatures would remain well below the 56°F upper water temperature objective for spawning salmonids. Compared with the No Action Alternative, the flow increases in December, January, and February under Alternative 4 would be unlikely to have substantial effects on the availability or suitability of steelhead spawning and egg/alevin incubation habitat.

Compared with the No Action Alternative, the change in seasonal operations in December, January, and February under Alternative 4 is expected to have few substantial impacts on the availability or suitability of steelhead spawning and egg/alevin incubation habitat.

Juvenile Rearing and Emigration

Rearing or moving (migrating or redistributing) fry and/or juveniles can occur downstream of Lewiston Dam any time of year, with peak emigration times in March, May/June, and October/November.

Potential Changes to Steelhead from Seasonal Operations

Seasonal operations under Alternative 4 would have spatially and temporally variable effects on the availability and suitability of rearing and emigration habitat for steelhead fry and juveniles. Compared with the No Action Alternative, substantial increases (greater than 5%) in modeled monthly average flows would occur in some water year types in December, January, and February and are described in detail in the preceding section and shown in Table O-264. In all other months and water year types there would be little or no difference in modeled monthly average flow between Alternative 4 and the No Action Alternative and no effects on steelhead would be expected in those months.

Compared with the No Action Alternative, the increased modeled monthly average flow in December of wet water years would increase WUA for steelhead fry and would decrease or result in no change in WUA for steelhead juveniles in the Trinity River from Lewiston Dam to Dutch Creek (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). From Dutch Creek to North Fork Trinity River and from North Fork Trinity River to South Fork Trinity River, WUA for steelhead fry and juveniles would decrease relative to the No Action Alternative. From South Fork Trinity River to Weitchpec, there would be an increase in WUA for steelhead fry and a decrease in WUA for steelhead juveniles.

In January of wet water years, the increased modeled monthly average flow relative to the No Action Alternative would result in an increase in steelhead fry WUA and a decrease in steelhead juvenile WUA from Lewiston Dam to Dutch Creek, a decrease in steelhead fry and juvenile WUA from Dutch Creek to North Fork Trinity River, and an increase in steelhead fry WUA and a decrease in steelhead juvenile WUA from North Fork Trinity River to South Fork Trinity River and South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). WUA for overwintering juvenile steelhead is predicted to respond somewhat differently, with a slight decrease in the reach from Dutch Creek to North Fork Trinity River and no change from North Fork Trinity River to South Fork Trinity River and from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). WUA for overwintering juvenile steelhead has not been quantified from Lewiston Dam to Dutch Creek at the range of monthly average flows that would occur in January of wet water years.

Compared with the No Action Alternative, the increased modeled monthly average flow in February of above normal water years would increase WUA for steelhead fry and would decrease or result in no change in WUA for steelhead juveniles in the Trinity River from Lewiston Dam to Dutch Creek (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). From Dutch Creek to North Fork Trinity River and from North Fork Trinity River to South Fork Trinity River, WUA for fry and juvenile steelhead would decrease relative to the No Action Alternative. From South Fork Trinity River to Weitchpec, the increased modeled monthly average flow under Alternative 4 would result in negligible decreases in steelhead fry and juvenile WUA relative to the No Action Alternative. WUA for overwintering juvenile steelhead would decrease slightly from Dutch Creek to Weitchpec relative to the No Action Alternative.

The modeled monthly average flow increases in December and January of wet water years and February of above normal water years under Alternative 4 would not result in measurable changes in modeled monthly average water temperatures compared with the No Action Alternative (Figure O-17). In these months and water year types, modeled monthly average water temperatures at Trinity River below Lewiston Dam under Alternative 4 would remain well below the 59°F water temperature objective for emigrating juvenile salmonids recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec and applicable prior to June 4, historical data and model results suggest that water temperatures in December, January, and February would remain below the 59°F objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for rearing or emigrating steelhead under Alternative 4 relative to the No Action Alternative. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton 2023) would likely be met under Alternative 4 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023). Despite the potential for exceedance of some water temperature objectives during this period at downstream locations in some water year types under Alternative 4, water temperatures and the potential effects on steelhead would not differ from the No Action Alternative.

Compared with the No Action Alternative, the change in seasonal operations under Alternative 4 would increase WUA for steelhead fry in the reach immediately downstream of Lewiston Dam and decrease steelhead fry WUA in most downstream reaches. There would be a slight decrease or no change in WUA for juvenile steelhead in most reaches of the Trinity River compared with the No Action Alternative. Substantial adverse impacts on steelhead would be unlikely under Alternative 4 .

Adult Upstream Migration and Holding

Consistent adult monitoring data are limited by environmental conditions and challenges in overlapping populations with different run timing, kelting or “runbacks,” and half pounders but summer/fall steelhead (stream-maturing steelhead) are thought to return from the ocean from approximately April through November and hold for varying lengths of time in the Klamath-Trinity watershed (Moyle et al. 2017, Moyle et al. 2015, Pinnix et al 2007). Winter steelhead (ocean-maturing steelhead) can return from the ocean about November through March (Moyle et al. 2017, Moyle et al. 2015, Pinnix et al 2007). Given the overlapping run timings and varying life history strategies, adults at various stages of maturation can enter the Klamath-Trinity watershed, hold in the Trinity River, and/or migrate up or down Trinity River and into tributaries in any month of the year.

Potential Changes to Steelhead from Seasonal Operations

In the Trinity River below Lewiston Dam, differences in modeled monthly average flow between Alternative 4 and the No Action Alternative would occur in some months and water year types and are described in detail in the preceding sections and shown in Table O-264. Compared with the No Action Alternative, minor reductions (less than 5%) in modeled monthly average flow under Alternative 4 would occur in November, December, February, and April of some water year types, and a minor increase (less than 5%) would occur in December, January, and March of some water year types. Substantial increases (greater than 5%) in modeled monthly average flow would occur in December and January of wet water years and in February of above normal water years. Monthly average flows would be equal to or greater than 300 cfs in all months and all water year types, and substantially greater in some months and water years, to provide suitable depth for adult steelhead passage. Flow increases in December and January of wet water years and in February of above normal water years may result in short-term changes in holding habitat for pre-spawning steelhead.

Compared with the No Action Alternative, the modeled monthly average flow increase in December of wet water years and February of above normal water years under Alternative 4 would result in a decrease in WUA for holding adult steelhead in the Trinity River from Dutch Creek to North Fork Trinity River, a slight increase from North Fork Trinity River to South Fork Trinity River, and a decrease from South Fork Trinity River to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). WUA for holding adult steelhead has not been quantified in the reach from Lewiston Dam to Dutch Creek for the range of flows that that would occur in December of wet water years. Wet and above normal water years make up 28% and 14% of the 100-year record, respectively. Overall, the availability and suitability of holding habitat for steelhead in these months and water year types may decrease under Alternative 4 compared with the No Action Alternative, potentially resulting in greater competition, predation risk, disease risk, and/or lower fitness of adult steelhead.

In January of wet water years, increased monthly average flow under Alternative 4 would result in a decrease in adult WUA overall across all reaches of the Trinity River from Dutch Creek to Weitchpec (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999) (WUA has not been quantified for flows greater than 800 cfs in the reach between Lewiston Dam and Dutch Creek). This may result in greater competition, predation risk, disease risk, and/or lower fitness of adult steelhead under Alternative 4 compared with the No Action Alternative.

The changes in modeled monthly flows in November through April of some water year types under Alternative 4 would have little or no effect on water temperatures in the Trinity River at Lewiston Dam (Figure O-10) and modeled monthly average water temperatures in these months and water year types would remain well below the 59°F water temperature objective for emigrating juvenile salmonids recommended for normal and wetter water year types (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Although the 59°F objective is intended to be measured at Weitchpec, historical data and model results suggest that water temperatures in November through April of normal and wetter water years would remain below the 59°F objective under a wide range of flow scenarios (Asarian et al. 2023) and there would be no change in the temperature suitability for adult steelhead under Alternative 4 relative to the No Action Alternative. The 61.7°F water temperature objective recommended by TRRP scientists to support juvenile salmonids upstream of the North Fork Trinity River in April–July (Buxton

2023) would likely be met under Alternative 4 through July at Douglas City but would not be met at the North Fork Trinity River confluence in June in drier water year types or in July in all water year types (Asarian et al. 2023) and should also be suitable for adults. Despite the potential for exceedance of some water temperature objectives during this period at downstream locations in some water year types under Alternative 4, water temperatures and the potential effects on steelhead adults would not differ from the No Action Alternative.

Compared with the No Action Alternative, the change in seasonal operations under Alternative 4 may reduce availability and suitability of holding habitat in December and January of wet water years and February of above normal water years. Wet and above normal water years together make up approximately 42% of the 100-year record. Therefore, the changes in flow under Alternative 4 may result in short-term adverse effects on holding adult steelhead in these months and water year types.

O.7.29 Northern DPS Green Sturgeon

O.7.29.1 Trinity River

Spawning and Egg Incubation

Northern DPS green sturgeon adults spawn primarily from March through July, though most spawning takes place from April to June (Section O.1.2.5.1, *Green Sturgeon, Northern* DPS). Northern DPS green sturgeon eggs hatch approximately a week after fertilization, and optimal temperatures for incubation range from 51.8–62.6°F (Van Eenennaam et al. 2005). The effects analysis period for incubating eggs is considered to be the same as the spawning period due to the short incubation period and includes March through July.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally be similar to flows under the No Action Alternative during spawning and egg incubation periods for green sturgeon. Compared with the No Action Alternative, modeled monthly average flows under Alternative 4 would increase slightly (less than 5%) in March of below normal and wetter water year types and decrease slightly (less than 5%) in April of above normal and wet water year types (Table O-264). The minor flow changes under Alternative 4 are not expected to affect suitability for green sturgeon spawning or egg incubation compared with the No Action Alternative.

Green sturgeon are only known to occur within the lower 43 miles of the Trinity River, ranging as far upstream as Grays Falls near Burnt Ranch, approximately 70 miles downstream of Lewiston Dam (Benson et al. 2007). Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries). Results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al.

2023). As a result, minor changes in seasonal operations are not likely to have a detectable influence on the water temperature suitability for green sturgeon spawning and egg incubation.

Larval and Juvenile Rearing and Emigration

The northern DPS green sturgeon spawning period is from March through July, and the larval period is considered to be March through September. The juvenile stage of green sturgeon begins when metamorphosis of the larva is complete, typically at about 45 days after hatching. Juveniles (up to 150 cm TL) typically migrate downstream slowly and rear in the Lower Klamath River for up to a year or until approximately their first summer, and optimal growth temperatures range from 59–66.2°F (Moyle 2002; Mayfield and Cech, Jr. 2004). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near Burnt Ranch to the Klamath River Estuary (Section O.1.2.5.1, *Green Sturgeon, Northern DPS*). The effects analysis period for larval and juvenile life stages in the Trinity River is considered to be April to September.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam would be nearly identical under Alternative 4 to flows under the No Action Alternative during larval and juvenile rearing and emigration periods for juvenile green sturgeon (Table O-264). Under Alternative 4, modeled monthly average flows would be the same as the No Action Alternative from April through September except for negligible differences (less than 5%) in April of above normal and wet water year types. Flows during the green sturgeon rearing and emigration period would correspond to the No Action Alternative flows that currently are managed to improve habitat conditions for anadromous fish. Under Alternative 4, modeled monthly average flows would have no effects on larval and juvenile rearing and emigration of green sturgeon when compared with the No Action Alternative.

Green sturgeon larvae and juveniles are only known to occur within the lower 43 miles of the Trinity River, and after hatching, they begin to migrate downstream. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River and results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations are not likely to have a detectable influence on the water temperature suitability for green sturgeon larval and juvenile rearing and emigration.

Adult Upstream Migration and Holding

Green sturgeon adults enter the Trinity River from the Klamath River Estuary as early as February and make their way upstream to spawn in deep pools in the lower section of the mainstem Trinity River, from its confluence with the Klamath River approximately 43 miles to Gray's Falls near Burnt Ranch. After spawning, the adults remain in mainstem river pools for varying amounts of time, representing distinct migration patterns. Directly after spawning, approximately 25% of adults emigrate back to the Klamath River estuary and ocean, but some may remain in fresh water for up to 199 days (Moyle 2002; Section O.1.3.2.5, *Green Sturgeon, Northern DPS*). With the extended adult holding period, the effects analysis period for adult upstream migration, holding, and emigration is considered to be February through December.

Potential Changes to Northern DPS Green Sturgeon from Seasonal Operations

Flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally be similar to flows under the No Action Alternative. Compared with the No Action Alternative, modeled monthly average flows under Alternative 4 would increase substantially (greater than 5%) in December and January of wet water years and in February of above normal water years (Table O-264). Minor changes (less than 5%) in modeled monthly average flow would occur in November, March, and April of some water year types. Throughout the February–December adult upstream migration, holding, and emigration period, flows under Alternative 4 would provide adequate passage and pool holding habitats and there would be no effects relative to the No Action Alternative.

Green sturgeon adults are only known to occur within the lower 43 miles of the Trinity River, and they have variable freshwater residence time (Benson et al. 2007). Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43, and smaller temperature differences are expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations are not likely to have a detectable influence on the water temperature suitability for adult green sturgeon during the migration, holding, and emigration period.

O.7.30 Eulachon

O.7.30.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean

Spawning and Egg Incubation

Eulachon adults spawn from December through May, with peak spawning occurring in March and April (Section O.1.2.6 *Eulachon*). Eulachon eggs hatch in 20 to 40 days depending on water temperature, with cooler temperatures leading to longer incubation times. Spawning is reported to occur at temperatures from 39 to 50°F; colder temperatures may stop migration (National Marine Fisheries Service 2017). Eulachon are broadcast spawners most commonly over sand, though spawning substrates can range from silt, sand or gravel to cobble and detritus (California

Department of Fish and Wildlife 2010; National Marine Fisheries Service 2017). Eulachon usually die after spawning. The effects analysis period for eulachon spawning and egg incubation is December through June.

Potential Changes to Eulachon from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally be similar to or greater than flows under the No Action Alternative during the eulachon spawning and egg incubation periods, with greater than 5% increases in December and January of wet water years and in February of above normal water years (Table O-264). The increase in flows would likely have negligible effects on eulachon spawning habitat and egg incubation. Under Alternative 4, modeled monthly average flows of 1,193 cfs in December of wet water years, 1,985 cfs in January of wet water years, and 1,393 cfs in February of above normal water years would maintain suitable spawning and egg incubation conditions for eulachon. Compared with the No Action Alternative, the flow increases under Alternative 4 are not expected to affect the availability or quality of spawning substrates and would have little or no effect on water temperature in the lower Klamath River.

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature within this section of the Klamath River below the confluence with the Trinity River is influenced by both the upper Klamath River and several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries). Previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 4 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for eulachon spawning and egg incubation.

Larval Emigration

Eulachon spawning occurs from December through May and eggs hatch in 20 to 40 days, so the larval period is considered to be January through June. After hatching, larval eulachon are quickly carried out to the ocean by river currents (Scott and Crossman 1973). Larval eulachon only remain in the Klamath River for about 5 days until they are washed out to sea. Larvae live on their yolk sac reserves after hatching—they do not feed while in fresh water (Gustafson et al. 2022). Effects of flow and water temperature on eulachon larvae in the Klamath River may occur from January through June.

Potential Changes to Eulachon from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally be similar to or greater than flows under the No Action Alternative during the eulachon larval emigration period, with greater than 5% increases in January of wet water years and February of above normal water years (Table O-264). The increase in flows

would likely have negligible effects on eulachon larval emigration. Under Alternative 4, modeled monthly average flows of 1,985 cfs in January of wet water years and 1,393 cfs in February of above normal water years would maintain suitable emigration conditions for eulachon. Compared with the No Action Alternative, the flow increases under Alternative 4 are not expected to affect larval transport or downstream passage and would have little or no effect on water temperature in the lower Klamath River.

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature within this section of the Klamath River below the confluence with the Trinity River is influenced by both the upper Klamath River and several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries). Previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 4 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for eulachon larval emigration.

Adult Upstream Migration

The spawning migration period for adult eulachon in the Klamath River begins in December and continues until May, with peak migration occurring in March and April (Yurok Tribal Fisheries Program 1998; Larson and Belchik 1998, Section O.1.2.6). Eulachon distribution in the Trinity River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Spawning occurs most commonly in sand-bedded areas but spawning substrates can range from silt, sand or gravel to cobble and detritus (California Department of Fish and Wildlife 2010; National Marine Fisheries Service 2017). The effects analysis period for eulachon adult upstream migration is December through May.

Potential Changes to Eulachon from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally be similar to or greater than flows under the No Action Alternative during the eulachon adult upstream migration period, with greater than 5% increases in December and January of wet water years and in February of above normal water years (Table O-264). The increase in flows would likely have negligible effects on eulachon adult upstream migration. Under Alternative 4, modeled monthly average flows of 1,193 cfs in December of wet water years, 1,985 cfs in January of wet water years, and 1,393 cfs in February of above normal water years would maintain suitable conditions for adult eulachon upstream migration. Compared with the No Action Alternative, the flow increases under Alternative 4 are not expected to affect the ability of adult eulachon to move upstream to spawning areas and would have little or no effect on water temperature in the lower Klamath River

Eulachon distribution in the Klamath River is limited to the lower approximately 24 river miles except during rare years when they are sometimes observed as far upstream as Pecwan Creek and even Weitchpec (Yurok Tribal Fisheries Program 1998). Water temperature within this section of the Klamath River below the confluence with the Trinity River is influenced by both the upper Klamath River and several tributaries that enter the Trinity River (e.g., Canyon Creek, North Fork Trinity River, New River, South Fork Trinity River, and small tributaries). Previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). As a result, minor changes in seasonal operations between Alternative 4 and the No Action Alternative are not likely to have a detectable influence on the water temperature suitability for eulachon adult upstream migration.

O.7.31 Coastal Cutthroat Trout

O.7.31.1 Lower Klamath River from Confluence With Trinity River to Pacific Ocean

Spawning and Egg Incubation

Generally, spawning of anadromous and resident coastal cutthroat trout may occur from September to April (Moyle 2002). Coastal cutthroat trout are associated with shaded streams and instream cover with water temperatures below 64°F, while preferred temperatures range from 48–54°F, with spawning temperatures of 43–63°F. (Moyle 2002). Spawning habitat is typically found in headwater streams with 1–3 feet/sec flow velocities and unembedded small- to medium-sized gravel (0.08–4 inches) (Moyle 2002). Embryos hatch about 6–7 weeks following incubation and alevins emerge 1–2 weeks thereafter (Moyle 2002).

The effects analysis period for coastal cutthroat trout spawning and egg incubation is September through June.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally be similar to or greater than flows under the No Action Alternative, with greater than 5% increases in December and January of wet water years and in February of above normal water years (Table O-264). The increase in Trinity River flows would be unlikely to affect the availability or suitability of coastal cutthroat trout spawning and egg incubation habitat, as most spawning is expected to occur in tributaries of the Trinity River and lower Klamath River. Compared with the No Action Alternative, there would be no changes in the availability or suitability of coastal cutthroat trout spawning and egg incubation habitat under Alternative 4 since Trinity River flows do not impact tributaries where coastal cutthroat trout typically spawn.

Juvenile Rearing and Emigration

Juvenile coastal cutthroat trout may spend anywhere from one to five years rearing in freshwater or a combination of freshwater and estuarine/ocean environments. Cutthroat fry are associated with slow water velocities (less than 1 foot/sec, with <0.3 feet/sec preferred), and are typically found in shaded streams with instream cover and water temperatures below 64°F. Preferred temperatures range from 48–54°F (Moyle 2002).

Most coastal cutthroat trout exhibiting an amphidromous life history leave their natal streams during summer, rear in estuaries, lagoons and nearshore ocean areas, and return to overwinter in freshwater (Moyle 2002). Anadromous forms may emigrate to estuaries or the ocean as juveniles in their first year or remain in freshwater for up to five years before entering ocean or estuarine environments. In Blue Creek, a Klamath River tributary, yearling and older cutthroat emigration occurred mainly between April and June (Moyle 2002). For individuals that emigrated to an estuary, Wallace (2004) found that the residence time within the estuary ranged from 5 to 89 days, with a mean of 27 days. Some populations, especially in California, migrate between large and small streams or between rivers and estuaries. Resident coastal cutthroat trout will remain in freshwater their entire lives, rather than emigrating to a lagoon or estuary or the ocean. Most coastal cutthroat trout in California, including those the Trinity River and lower Klamath River, are weakly anadromous, spawning in tributaries and moving primarily between tributaries and the larger rivers and estuary (Moyle 2002).

The effects analysis period for coastal cutthroat trout juvenile rearing and emigration is April through June for amphidromous coastal cutthroat trout and January through December (year-round) for resident coastal cutthroat trout.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally be similar to or greater than flows under the No Action Alternative, with greater than 5% increases in December and January of wet water years and February of above normal water years (Table O-264). The increase in flows would likely have negligible effects on coastal cutthroat trout juvenile rearing and emigration habitat. Under Alternative 4, modeled monthly average Trinity River flows of 1,193 cfs in December of wet water years, 1,985 cfs in January of wet water years, and 1,393 cfs in February of above normal water years would maintain suitable rearing and emigration conditions for coastal cutthroat trout in the Trinity River and lower Klamath River. Compared with the No Action Alternative, the flow increases under Alternative 4 are not expected to affect conditions for rearing or downstream passage, especially since most rearing occurs in natal tributaries and in estuaries, lagoons, and nearshore ocean environments. Modeled monthly average flow increases in the Trinity River may slightly improve emigration conditions in the Trinity River but the effects on flow and water temperature in the lower Klamath River would be negligible and unlikely to influence emigration conditions for coastal cutthroat moving downstream toward the ocean or estuary.

Water temperature and habitat conditions within the Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023).Compared with the No Action Alternative, the maximum increases in modeled monthly average flow under Alternative 4 range from 60 cfs to 199 cfs depending on month and water year type. As a result, minor changes in seasonal operations between Alternative 4 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for coastal cutthroat trout juvenile rearing and emigration.

Seasonal operations under Alternative 4 are expected to maintain suitable habitat conditions for coastal cutthroat trout juvenile rearing and emigration in the Trinity River, lower Klamath River, and the Klamath River estuary. Compared with the No Action Alternative, changes in the availability or suitability of coastal cutthroat trout juvenile rearing and emigration habitat would be negligible.

Adult Holding and Migration

Migration of coastal cutthroat trout to freshwater typically occurs between August and October between the ages of one and five (Moyle 2002). While most anadromous salmonids die after completing spawning, coastal cutthroat may survive spawning, re-enter the ocean, and return the following year(s) to spawn up to five times (Moyle 2002). Overwintering coastal cutthroat trout prefer pools with cover (e.g., logs, undercut banks, boulders) (Moyle 2002).

The effects analysis period for coastal cutthroat trout adult holding and migration is August through October for amphidromous coastal cutthroat trout and January through December for resident coastal cutthroat trout.

Potential Changes to Coastal Cutthroat Trout from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally be similar to or greater than flows under the No Action Alternative, with greater than 5% increases in December and January of wet water years and February of above normal water years (Table O-264). The increase in flows would likely have negligible effects on coastal cutthroat trout adult holding and migration habitat. Under Alternative 4, modeled monthly average Trinity River flows of 1,193 cfs in December of wet water years, 1,985 cfs in January of wet water years, and 1,393 cfs in February of above normal water years would maintain suitable rearing and emigration conditions for coastal cutthroat trout in the Trinity River and lower Klamath River. Compared with the No Action Alternative, the flow increases under Alternative 4 would have negligible effects on conditions for adult upstream passage and no effect on holding which would occur in tributaries unaffected by mainstem river flows.

Water temperature and habitat conditions within the Klamath River below the confluence with the Trinity River are influenced by both the upper Klamath River and several tributaries that enter the Trinity River. Results of previous water temperature modeling for the Trinity River predicted a difference of less than 1°F in April water temperature for flows of 300 cfs and 450 cfs near the confluence of the Trinity and Klamath Rivers (U.S. Fish and Wildlife Service & Hoopa Valley Tribe 1999). Recent synthesis of Trinity River temperature data described a cooling effect of up to 3.4°F per 1,000 cfs at the Klamath/Trinity River confluence from Lewiston Dam releases (Asarian et al. 2023). Compared with the No Action Alternative, the maximum increases in modeled monthly average flow under Alternative 4 range from 60 cfs to 199 cfs depending on month and water year type. As a result, minor changes in seasonal operations between Alternative 4 and the No Action Alternative are unlikely to have a detectable influence on the water temperature suitability for coastal cutthroat trout adult migration.

Seasonal operations under Alternative 4 are expected to maintain suitable habitat conditions for coastal cutthroat trout adult migration in the Trinity River and lower Klamath River. No effects on adult holding are expected. Compared with the No Action Alternative, changes in the availability or suitability of coastal cutthroat trout adult migration habitat would be negligible.

O.7.32 Brown Trout

O.7.32.1 Trinity River

Spawning and Egg Incubation

Brown trout spawn in fall and winter, most commonly in November and December in California (Moyle 2002). Trout typically mature and spawn in their second or third year, but they may wait longer (7 or 8 years) (Moyle 2002). Adults begin selecting spawning locations when water temperatures are between 42.8–50ºF (Moyle 2002). Spawning habitat comprises pea- to walnut-sized gravel in less turbulent waters, which are typically found at pool tailouts (Moyle 2002). Embryos hatch in seven to eight weeks (ranging from 4–21 weeks), with alveins emerging three to six weeks later, depending on water temperature.

The effects analysis period for brown trout spawning and egg incubation is November through April.

Potential Changes to Brown Trout from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally similar to or greater than flows under the No Action Alternative during the brown trout spawning and egg incubation period, with greater than 5% increases in December and January of wet water years and in February of above normal water years (Table O-264). Under Alternative 4, modeled monthly average flows of 1,193 cfs in December of wet water years, 1,985 cfs in January of wet water years, and 1,393 cfs in February of above normal water years would maintain suitable spawning and egg incubation conditions for brown trout. Compared with the No Action Alternative, the flow increases under Alternative 4 are not expected to affect the availability or quality of spawning substrates and would have little or no effect on water temperature in the lower Klamath River Compared to the No Action Alternative, changes in the availability or suitability of brown trout spawning and egg incubation habitat would be minimal and unlikely to have adverse impacts on brown trout.

Juvenile Rearing and Emigration

The ideal temperature range for brown trout is between 53.6–68°F, with optimal growth between 62.6–64.4°F; they can survive for only short period at higher temperatures up to 84.2°F (Moyle 2002). Cold temperatures reduce brown trout's ability to effectively capture prey: when temperatures reduced from 58.5°F to 42.3°F the foraging effectiveness reduced from 96% to 53% (Watz and Piccolo 2010).

In California, brown trout reach 2–3 inches in length their first year, 5–6 inches in their second year, 8–11 inches in their third, and 14–16 inches in their fourth year (Moyle 2002). Fry rear in edge-water habitat that is slow and shallow (<12 inches deep), with juveniles selecting riffles and pools with deeper water (20–30 inches), higher velocities (0.3–1.3 feet/second), and cover from overhead, rocks, and logs (Moyle 2002). It is uncertain the degree to which brown trout exhibit an anadromous life history in the Trinity River, with juveniles emigrating to the ocean, or are riverine (potamodromous) with juveniles emigrating further downstream while continuing to remain in freshwater. In Ireland, where they are native, brown trout juveniles emigrated to brackish or marine habitats throughout the year, with distinct seasonal peeks in spring (March through June) and fall (September through December) (Wynne et al. 2023).

The effects analysis period for brown trout juvenile rearing and emigration is January through December.

Potential Changes to Brown Trout from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally similar to or greater than flows under the No Action Alternative during the brown trout spawning and egg incubation period, with greater than 5% increases in December and January of wet water years and in February of above normal water years (Table O-264). Under Alternative 4, modeled monthly average flows of 1,193 cfs in December of wet water years, 1,985 cfs in January of wet water years, and 1,393 cfs in February of above normal water years would maintain suitable juvenile rearing and emigration conditions for brown trout. Compared with the No Action Alternative, the flow increases under Alternative 4 are not expected to affect the availability of rearing habitat or emigration conditions and would have little or no effect on water temperature in the lower Klamath River. Seasonal operations under Alternative 4 are expected to maintain suitable habitat conditions for brown trout juvenile rearing and emigration in the Trinity River. Compared to the No Action Alternative, changes in the availability or suitability of brown juvenile rearing and emigration habitat would be minimal and unlikely to have adverse impacts on brown trout.

Adult Holding and Migration

Upstream migration occurs in fall and winter, prior to spawning, which most commonly occurs in November and December. Sullivan and Hilemean (2018) noted a shift in migration timing on the Trinity River to later in the season following the implementation of the Record of Decision (ROD) flows (2005-2011, 2017), as compared to Pre-ROD flows (1982–2002). In rivers, adults will hold in a wide range of habitats, but are often associated with low velocity pools ranging from 2.3–11.5 feet deep that have cover (Moyle 2002).

The effects analysis period for brown trout adult holding and migration is January through December with migration primarily in November and December.

Potential Changes to Brown Trout from Seasonal Operations

Modeled monthly average flows in the Trinity River downstream of Lewiston Dam under Alternative 4 would generally similar to or greater than flows under the No Action Alternative during the brown trout adult holding and migration period, with greater than 5% increases in December (Table O-264). Under Alternative 4, modeled monthly average flows of 1,193 cfs in December of wet water years would maintain suitable adult holding and migration conditions for brown trout. Compared with the No Action Alternative, the flow increases under Alternative 4 are not expected to affect the availability of adult holding or migration conditions and would have little or no effect on water temperature in the lower Klamath River. Seasonal operations under Alternative 4 are expected to maintain suitable habitat conditions for brown trout adult holding and migration in the Trinity River. Compared to the No Action Alternative, changes in the availability or suitability of brown trout adult holding and migration habitat would be minimal and unlikely to have adverse impacts on brown trout.

O.7.33 Trinity Reservoir Species

O.7.33.1 Trinity Reservoir

Spawning and Egg Incubation

Coldwater fish species (rainbow trout, brown trout, Kokanee, and landlocked Chinook salmon) in the lake generally migrate into tributaries to spawn either from December through March (rainbow trout), November–December (brown trout), or August through April (kokanee). Populations of rainbow trout, brown trout, and Kokanee are sustained through a combination of natural reproduction and fish hatchery stocking practices. Landlocked Chinook salmon do not typically reproduce (Perales et al. 2015) and are supported by annual stocking practices.

Warmwater fish species (smallmouth bass, largemouth bass, white catfish, and brown bullhead) typically rely on habitat in the lake during all life stages. In general, smallmouth and largemouth bass spawn from April through July in shallow water (1.5 feet to 6.0 feet deep) along the lake margins at water temperatures ranging from 55°F to 75°F (Moyle 2002). These nests are vulnerable to fluctuations in water levels. Rapid drops in water levels may cause guarding males to abandon the nests, increase predation, and limit water circulation and dissolved oxygen levels around the eggs (Edwards et al. 1983). White catfish spawning typically occurs during June and July when water temperatures exceed 68°F, but spawning can sometimes extend into September; spawning occurs in sandy substrate adjacent to cover (e.g., rocks, wood, or aquatic vegetation) and eggs hatch in about a week (Moyle 2002). Brown bullhead spawn from May through mid-July and will build their nests in sand or gravel near cover (Moyle 2002). Warmwater fish species in Trinity Lake are currently self-sustaining through natural reproduction.

The effects analysis period for coldwater fish species spawning and egg incubation is August through April. The effects analysis period for warmwater fish species spawning and egg incubation is April through September.

Potential Changes to Trinity Reservoir Fish Species from Seasonal Operations

Trinity Reservoir storage under Alternative 4 would generally be higher than storage under the No Action Alternative (Table O-265) but all inor differences would be negligible (<5%) and unlikely to reduce the availability or suitability of spawning and egg incubation habitat for Trinity Reservoir fish species.

Larval and Juvenile Rearing and Emigration

Rainbow trout fry emerge 3–4 weeks after fertilization and will remain in the gravel for about 2–3 weeks (Moyle 2002, USFWS 1984, Habitat Suitability Information: Rainbow Trout, FWS/OBS-82/10.60). Juvenile rainbow trout may spend two summers in their natal stream and two summers in a reservoir or lake before maturing. Brown trout fry typically hatch in 2 months, though it can range from 1–5 months depending on water temperature, and larvae will emerge from the gravel around 1 month later. Juveniles will spend several years in tributaries before emigrating to the reservoir where they will become sexually mature (Moyle 2002, Belica 2007).

Smallmouth and largemouth bass fry prefer shallow water and are vulnerable to fluctuations in water levels. These fry hatch in 2–7 days and then spend another week in the nest. Larval bass stay in shallow water on the edge of vegetation (Moyle 2002). Rapid drops in water levels may cause stranding. Juvenile bass tend to live in deeper water habitats with submerged shelter (e.g., logs or boulders). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002).

The effects analysis period for both coldwater and warmwater fish species larval and juvenile rearing and emigration is January through December.

Potential Changes to Trinity Reservoir Fish Species from Seasonal Operations

Trinity Reservoir storage under Alternative 4 would generally be higher than storage under the No Action Alternative (Table O-265) but all changes would be minor (<5%) and None of these changes are likely to have a detectable influence on the water temperature and habitat suitability for larval and juvenile rearing and emigration of Trinity Reservoir coldwater or warmwater fish species.

Adult Holding

The life expectancy of rainbow trout can be 4–8 years in northern California lake populations. After maturing, resident rainbow trout will migrate upstream to spawn in tributaries. They can spawn annually and will quickly move back downstream to the reservoir or lake (Moyle 2002), moving to cooler, deeper waters during the summer months (Belica 2007). Brown trout typically become sexually mature at age two or three and have been found as old as can live for up to nine years in California, spawning several times during their life (Moyle 2002, Belica 2007). Brown trout will use varying habitats within the reservoir and will also move to cooler waters in the summer habitats (Belica 2007).

Warmwater species will remain in the reservoir their entire lives. Smallmouth bass prefer narrow bays and upstream ends of reservoirs or along the shore where rocky shelves are present at a depth of 1–10m (Moyle 2002). They become sexually mature at age 3–4 and typically live less than 7 years (Edwards et al. 1983). Age of largemouth bass in California reservoirs is four and five years and they typically spawn during their second season (Moyle 2002). Adult bass tend to prefer deeper, colder waters in lakes and reservoirs in areas with vegetation and other forms of cover (Edwards et al. 1983). White catfish will move throughout the reservoir and don't have a regular seasonal migration, thought they tend to concentrate at depts of 10–30 ft but will move deeper in the summer as temperatures increase (Moyle 2002). Brown bullhead typically live in deeper water (6–30 ft deep) in areas with aquatic plants and muddy substrate (Moyle 2002). They become sexually mature at age 3 and will spawn multiple times during their lifetime of up to eight to ten years (Moyle 2002).

The effects analysis period for both coldwater and warmwater fish species adult holding is January through December.

Potential Changes to Trinity Reservoir Fish Species from Seasonal Operations

Trinity Reservoir storage under Alternative 4 would generally higher than storage under the No Action Alternative (Table O-265) but all modeled changes would be minor (<5%) and none of these changes are likely to have a detectable influence on the water temperature and habitat suitability for adult holding of Trinity Reservoir coldwater or warmwater fish species.

O.7.34 Central Valley Reservoir Species

O.7.34.1 Potential Changes to Central Valley Reservoir Species from Seasonal Operations

Shasta Reservoir

Warmwater Species

Reductions in Shasta Reservoir WSE month-over-month reductions of six feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Shasta_2.

For Alternative 4, there would be between two more to eight fewer WSE reductions of six feet or more compared to the No Action Alternative. These results indicate that Alternative 4 would have a beneficial effect on warmwater species in Shasta Reservoir.

Coldwater Species

Shasta Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Shasta_1.

For Alternative 4, end-of-month storage would be similar to storage under the No Action Alternative in wet, above normal, below normal, and dry water years and 5.0 to 12.8% higher than the No Action Alternative in critical water years. These results indicate that there would be negligible and beneficial effects of Alternative 4 on coldwater species in Shasta Reservoir.

Whiskeytown Reservoir

Coldwater and Warmwater species

Reductions in Whiskeytown Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Whiskey_2.

For Alternative 4, there would be no or negligible difference in WSE month-over-month reductions of six feet or more relative to the No Action Alternative. Therefore, there would be no effect or negligible effects of Alternative 4 on warmwater species in Whiskeytown Reservoir.

Coldwater Species

Whiskeytown Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Whiskey_1.

End-of-month storage volume under Alternative 4 would be similar to that of the No Action Alternative. These results indicate that Alternative 4 would have negligible effects on coldwater species in Whiskeytown Reservoir.

Folsom Reservoir

Coldwater and Warmwater Species

Reductions in Folsom Reservoir WSE month-over-month reductions of six feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Folsom_2.

There would be zero to four more reductions of six feet or more under Alternative 2 than under the No Action Alternative depending on month. These results indicate that there would be a negligible negative effect of Alternative 4 on warmwater species in Folsom Reservoir.

Coldwater Species

Folsom Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Folsom_1.

For Alternative 4, end-of-month storage would be similar to storage under the No Action Alternative in wet, above normal, below normal, and dry water years and 14.4 to 20.4% higher than the No Action Alternative in critical water years. These results indicate that there would be negligible and beneficial effects of Alternative 4 on coldwater species in Folsom Reservoir.

New Melones Reservoir

Warmwater Species

Reductions in New Melones Reservoir WSE month-over-month reductions of six feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects of seasonal operations on warmwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Melones 2.

For Alternative 4, here would be zero to two fewer WSE month-over-month reductions of six feet or more than the No Action Alternative depending on month. These results indicate that there would be negligible effects of Alternative 3 on warmwater species in New Melones Reservoir.

Coldwater Species

New Melones Reservoir end-of-month storage volume during April through October for each alternative was compared to the No Action Alternative to assess potential effects of seasonal operations on coldwater reservoir species. Please see Section O.4.33.2, *Methods*, for a description of the methods used for this analysis. Results are presented in Table Melones_1.

For Alternative 4, there would be negligible differences in storage volume throughout the period analyzed compared to the No Action Alternative. This indicates that Alternative 4 would have negligible effects on coldwater species in New Melones Reservoir.

O.7.35 Delta-Mendota Canal / California Aqueduct Species

O.7.35.1 Potential Changes to Delta-Mendota Canal/California Aqueduct Species from Seasonal Operations

Water from the Delta is diverted through the California Aqueduct and Delta-Mendota Canal and held for off-stream storage (e.g., in San Luis Reservoir) and there is no coldwater habitat in the Delta-Mendota Canal. Therefore, no analysis of coldwater habitat was conducted. Warmwater species such as black basses and striped bass support recreational fishing in the California Aqueduct. Water velocity in the canal is not specifically managed to support or enhance recreational fisheries. Increases in water velocity may decrease water temperatures and flowing water for species, improving conditions; while decreases in water velocity may increase water temperatures and lead to stagnant water for species, diminishing conditions.

Differences in flows and velocity under Alternative 4, compared to the No Action Alternative, are expected to be minimal thus, impacts to species present are not expected to change.

O.7.36 San Luis Reservoir Species

O.7.36.1 Potential Changes to San Luis Reservoir Species from Seasonal Operations

Warmwater Species

Reductions in San Luis Reservoir WSE month-over-month reductions of 6 feet or more during March through June under each alternative were compared to reductions under the No Action Alternative to assess potential effects. Please see Section O.4.33.2, *Methods,* for details on the methods used in this analysis. Results are presented in Table SLR_1.

For Alternative 4, there would be 20 fewer to 2 more WSE month-over-month reductions of 6 feet or more than under the No Action Alternative depending on month. These results indicate that there would be predominantly beneficial effects of Alternative 4 on warmwater species in San Luis Reservoir.

O.7.37 Southern Resident Killer Whale

O.7.37.1 Nearshore Pacific Ocean on the California Coast

Changes in water operations under the alternatives could have the potential to affect Chinook salmon prey for Southern Resident Killer Whale (Southern Resident) relative to the No Action Alternative. Outlined below are expected changes in Southern Resident prey. Four lines of evidence were used (Salmort, XT, CVPIA SIT LCM, and DPM), and Attachment F.7, *Change in Abundance Estimate of Central Vally Chinook Salmon Available to Southern Resident Killer Whales*, provides detailed results of all models and analyses.

Based on the lines of evidence, Alternative 4 is predicted to have an annual median abundance of about 232,812 Chinook salmon that survive to adulthood or about 3,495,669 pounds of Chinook salmon biomass in the ocean available as potential prey to Southern Residents. This is about 61 more Chinook salmon or 923 pounds more than the No Action Alternative. This is likely a negligible difference in Chinook salmon and biomass available to Southern Residents for prey between the No Action Alternative and Alternative 4.

O.8 Summary of Impacts

Table O-282, Summary of Aquatic Resources Impacts, includes a summary of impacts. Avoidance and minimization measures and potential mitigation measures can be found in more detail in Section O-9, *Mitigation Measures*, and Appendix D, *Mitigation Measures*. In general, given the complexity and length of the Fish and Aquatic Resources analyses, the table focuses on the direction of changes under each alternative. The magnitude of the changes is discussed within Appendix O and Chapter 12, *Fish and Aquatic Resources*.

Table O-282. Summary of Aquatic Resources Impacts

Impact	Alternative	Direction of Impacts
SACRAMENTO RIVER WINTER-RUN CHINOOK SALMON ESU		
Sacramento River		
Potential changes to winter-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations. The No Action Alternative results in impacts and benefits to winter-run Chinook salmon including coldwater pool management. • **Adverse Components:** Fall Operations and Rice Decomposition Smoothing, Fall and Winter Refill and Redd Maintenance. • **Potential Beneficial Components:** Ramping Rates, Spring Pulse Flows, Water Temperature Management, Winter-run Chinook Salmon Supplementation
	Alternative 1	• **Spawning and Egg/Alevin Incubation:** Possible adverse to beneficial impacts from *flow* on spawning habitat and redd dewatering potential, adverse impacts on spawner abundance and female escapement. Adverse impacts from *water temperatures* on incubating eggs from TDM, beneficial impacts from *water temperatures* on spawning adults and egg/alevin incubation. • **Juvenile Rearing and Emigration:** Potential adverse and beneficial impacts from *flow* on fry and juvenile rearing habitat adverse impacts on fry survival during critically dry years. Beneficial impacts on survival and travel time. Beneficial impacts from *water temperatures*. • **Adult Migration and Holding:** Beneficial impacts from *flow*, flows high enough to allow upstream passage. Negligible adverse impacts from *water temperatures*.
	Alternative 2 [1]	• **Spawning and Egg/Alevin Incubation:** Possible adverse to beneficial impacts from *flow* on spawning habitat and redd dewatering potential, possible adverse and beneficial impacts on spawner abundance. Possible beneficial impacts from *water temperatures* from TDM, beneficial impacts on spawning and egg/alevin incubation, negligible adverse impacts specific to egg incubation and fry emergence.

[1] Language for Alternative 2 refers to across all four phases of Alternative 2, unless otherwise stated.

Impact	Alternative	Direction of Impacts
		• **Juvenile Rearing and Emigration:** Potential adverse to beneficial impacts from *flow* on fry and juvenile rearing habitat, beneficial impacts on fry stranding, adverse to beneficial impacts on juvenile production index (depending on the phase). Adverse to beneficial impacts on fry survival and juvenile survival and travel time. Adverse to beneficial impacts from *water temperatures* on juvenile rearing and emigration. • **Adult Migration and Holding:** Potential adverse to beneficial impacts from *flow*, generally beneficial impacts early in the season (December: January) and adverse impacts later in the season (May and June), flows high enough to allow upstream passage. Negligible adverse impacts from *water temperatures* on upstream migrating and holding adults.
	Alternative 3	• **Spawning and Egg/Alevin Incubation:** Potential adverse to beneficial impacts from *flow* on spawning habitat and redd dewatering potential, potential adverse or beneficial impacts on spawner abundance depending on water year type, potential beneficial impacts on female escapement. Potential beneficial impacts from *water temperatures*, while potential adverse impacts on egg to fry survival, potential beneficial impacts on spawning and egg/alevin, adverse impacts on spawning initiation and egg incubation and fry emergence from water temperatures analysis. • **Juvenile Rearing and Emigration:** Potential adverse to beneficial impacts from *flow* on fry and juvenile rearing habitat, beneficial impacts on fry survival particularly in critically dry years. Potential adverse to beneficial impacts on travel time and beneficial impacts on survival. Potential beneficial impacts from *water temperatures*. • **Adult Migration and Holding:** Potential adverse to beneficial impacts from *flow*, flows high enough to allow upstream passage. Adverse impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg/Alevin Incubation:** Potential adverse impacts from *flow* on spawning habitat, beneficial impacts in a critically dry water year type, adverse to beneficial impacts on spawner abundance; beneficial impacts on female escapement. Potential beneficial impacts from *water temperatures*, adverse to beneficial impacts on spawning and egg/alevin incubation from water temperatures analysis. • **Juvenile Rearing and Emigration:** Potential adverse to beneficial impacts from *flow* on fry and juvenile rearing habitat, potential beneficial impacts on fry stranding, adverse impacts on juvenile production index, beneficial impacts on fry survival particularly in critically dry years. Potential adverse to beneficial impacts in all water year types on survival and travel time in the upper Sacramento River. Potential adverse and beneficial impacts from *water temperatures*. • **Adult Migration and Holding:** Potential beneficial impacts from *flow*, except June of a critically dry years; flows high enough to allow upstream passage. Negligible adverse impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
Bay-Delta		
Potential changes to winter-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Spring Delta Outflow. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	Possibly less flow into CVP under OMR -2,000 and -5,000, Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 2	Negligible impacts on flow into HOR. Alternatives without VA may have minimal less flow into CVP under OMR -2,000; alternatives with VA may have negligible impacts on flow into CVP. Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 3	Potential little to less flow into CVP under OMR -3,500, Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 4	Potential little to less flow into CVP under OMR -2,000, impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
Potential changes to entrainment of winter-run Chinook salmon	No Action	No measurable change from current conditions, continuation of current trends. • **Beneficial:** Seasonal and Real-time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** DCC Gates Operations, RRDS Fall Flood-up, Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	Adverse impacts from *flow* on entrainment of genetically and LAD identified juveniles.
	Alternative 2	2 phases of Alternative 2 with VA expected to have overall beneficial impacts from *flow* on entrainment of juveniles, except during a wet water year type. 2 phases of Alternative 2 without VA could have adverse to beneficial impacts, depending on water year type and quantitative model.
	Alternative 3	Potential beneficial impacts from *flow* on entrainment of juveniles, particularly in WYTs with better conditions (wet, above normal, below normal). Potential adverse impacts on entrainment, particularly in dry and critically dry years.
	Alternative 4	Potential adverse impacts from *flow* on entrainment of juveniles, except at CVP in critically dry and dry WYT where there may be beneficial impact.

Impact	Alternative	Direction of Impacts
Potential changes to routing of winter-run Chinook salmon	No Action	No change from current conditions, included under seasonal operations.
	Alternative 1	Potential adverse and beneficial impacts from *flow* on routing into the Interior Delta.
	Alternative 2	Potential adverse and beneficial impacts from *flow* on routing into the Interior Delta.
	Alternative 3	Potential adverse and beneficial impacts from *flow* on routing into the Interior Delta.
	Alternative 4	Potential adverse and beneficial impacts from *flow* on routing into the Interior Delta.
Potential changes to through Delta survival of winter-run Chinook salmon	No Action	No measurable change from current operations and trends, included under seasonal operations.
	Alternative 1	Potential adverse impacts from *flow* on survival of outmigrating juveniles.
	Alternative 2	Potential adverse or beneficial impacts from *flow*..
	Alternative 3	Potential adverse or beneficial impacts from *flow*.
	Alternative 4	Potential adverse or beneficial impacts from *flow*.
CENTRAL VALLEY SPRING-RUN CHINOOK SALMON ESU		
Sacramento River		
Potential changes to spring-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations and trends. • **Adverse Components:** Fall Operations and Rice Decomposition Smoothing, Fall and Winter Refill and Redd Maintenance. • **Beneficial Components:** Ramping Rates, Water Temperature Management, and Spring Pulse Flows.
	Alternative 1	• **Spawning and Egg/Alevin Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat. Potential adverse impacts on redd dewatering during wet and above normal water years. Beneficial impact from *water temperatures* on spawning below Keswick Dam and pathogen virulence at Red Bluff Diversion Dam. Adverse impacts on egg/alevin incubation below Keswick Dam. • **Juvenile–Yearling Rearing and Emigration:** Adverse impacts from *flow* on fry and juvenile rearing habitat depending on water year type. Beneficial impacts on fry and juvenile rearing during critically dry years. Adverse impacts on fry stranding in most water years and beneficial impacts in critically dry years. Adverse and beneficial impacts from *water temperatures* on growth, smoltification, and predation vulnerability. • **Adult Migration and Holding:** Flows high enough to allow upstream passage. Negligible impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
	Alternative 2	• **Spawning and Egg/Alevin Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat. . Potential adverse to beneficial impacts from *flow* on redd dewatering potential (depending on water year type). Adverse and beneficial impacts from *water temperatures* on spawning and egg/alevin incubation. • **Juvenile–Yearling Rearing and Emigration:** Adverse impacts from *flow* on fry rearing habitat and beneficial and adverse impacts on juvenile rearing habitat. For juvenile stranding, all phases show beneficial impacts in wet and above normal water years and a mix of beneficial and adverse impacts for drier years. Beneficial impacts on juvenile survival due to a decrease in travel time. Potential adverse or beneficial impacts from *water temperatures* on juvenile and yearling growth, smoltification, and predation vulnerability. • **Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on upstream migration and holding adults. Flows high enough to allow upstream passage. Negligible adverse impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg/Alevin Incubation:** Possible beneficial impacts from *flow* on spawning habitat, redd dewatering potential. Beneficial impacts from *water temperatures* on spawning, egg/alevin incubation and pathogen virulence. • **Juvenile–Yearling Rearing and Emigration:** Possible adverse and beneficial impacts from *flow* on juvenile and yearling rearing habitat. Negligible adverse impacts on stranding except for adverse impacts during critically dry years. Potential adverse to beneficial impacts on travel time and beneficial impacts on juvenile survival (depending on water year type). Adverse and beneficial impacts from *water temperatures*, except at Keswick Dam where there would be an adverse impact on fry and yearling juvenile life stages. Negligible adverse impacts on lethal water temperatures. • **Adult Migration and Holding:** Potential adverse to beneficial impacts from *flow*, flows high enough to allow upstream passage. Negligible adverse impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg/Alevin Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat, spawner abundance, and egg/alevin incubation. Adverse to beneficial impacts on redd dewatering potential (depending on water year type). Potential adverse to beneficial impacts from *water temperatures* on spawning and egg/alevin incubation. • **Juvenile–Yearling Rearing and Emigration:** Potential adverse to beneficial impacts from *flow* on fry and juvenile rearing habitat. Adverse and beneficial impacts on stranding (depending on water year type). Beneficial impacts from *flow* on juvenile survival and travel time. Adverse and beneficial impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
		• **Adult Migration and Holding:** Negligible adverse impacts from *flow*. Flows are high enough to allow upstream passage. Negligible impacts from *water temperatures*.
Clear Creek		
Potential changes to spring-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations. • **Adverse and/or Beneficial:** Summer and Fall Operations. • **Beneficial:** Ramping Rates, Segregation Weir, Minimum Instream Flows, Pulse Flows, Water Temperature Management, and Spawning and Rearing Habitat.
	Alternative 1	• **Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat area. Negligible impacts from *water temperatures*. • **Juvenile–Yearling Rearing and Emigration:** Adverse impacts from *flow* on fry rearing habitat and adverse impacts on juvenile rearing habitat. Negligible adverse impacts from *water temperatures*. • **Adult Migration and Holding:** Adverse impacts from *flow* on adult migration and holding. Negligible impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat area. No anticipated impacts from *water temperatures*. • **Juvenile–Yearling Rearing and Emigration:** Beneficial impacts from *flow* on fry rearing habitat and adverse impacts on juvenile rearing habitat. Negligible impacts from *water temperatures*. • **Adult Migration and Holding:** Adverse impacts from *flow* and no anticipated impact from *water temperatures*.
	Alternative 3	• **Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat area. No anticipated impacts from *water temperatures* on spawning, pathogen virulence, or egg incubation and fry emergence. • **Juvenile–Yearling Rearing and Emigration:** Beneficial impacts from *flow* on fry rearing habitat and adverse impacts on juvenile rearing habitat. Negligible impacts from *water temperatures* on juvenile and yearling rearing and lethal water temperatures. • **Adult Migration and Holding:** Adverse impacts from *flow* on adult migration and holding. No anticipated impacts from *water temperatures* on adult migration and holding.
	Alternative 4	• **Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat area. No anticipated impacts from *water temperatures* on spawning, pathogen virulence, and egg incubation and fry emergence. • **Juvenile–Yearling Rearing and Emigration:** Beneficial impacts from *flow* on fry rearing habitat and adverse impacts on juvenile rearing habitat. Negligible adverse impacts from *water temperatures* on juvenile and yearling rearing and lethal temperature threshold (UILT).

Impact	Alternative	Direction of Impacts
		• **Adult Migration and Holding:** Adverse impacts from *flow*. No anticipated impacts from *water temperatures* on adult migration and holding.
Bay-Delta		
Potential changes to spring-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations. • **Adverse:** Agricultural Barriers. • **Beneficial:** Spring Delta Outflow • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	**Juvenile–Yearling Rearing and Emigration:** Possibly less flow into CVP under OMR -2,000 and -5,000 Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 2	**Juvenile–Yearling Rearing and Emigration:** Negligible impacts on *flow* into HOR. Alternatives without VA may have minimal less flow into CVP under OMR -2,000; alternatives with VA may have negligible impacts on flow into CVP. Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 3	**Juvenile–Yearling Rearing and Emigration:** Potential less flow into CVP under OMR -3,500. Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 4	**Juvenile–Yearling Rearing and Emigration:** Potential less *flow* into CVP under OMR -2,000. Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
Potential changes to entrainment of spring-run Chinook salmon	No Action	No measurable change from current conditions, continuation of current trends. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** Suisun Marsh RRDS Fall Flood-up, DCC Gates, and Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility.
	Alternative 1	**Juvenile–Yearling and Emigration:** Adverse impacts from *flow* on entrainment at both fish facilities.
	Alternative 2	**Juvenile–Yearling and Emigration:** Adverse impacts from *flow* on monthly loss at SWP and salvage. Beneficial impacts at CVP for loss.
	Alternative 3	**Juvenile–Yearling and Emigration:** Beneficial impacts from *flow* on entrainment and salvage at both fish facilities
	Alternative 4	**Juvenile–Yearling and Emigration:** Adverse impacts from *flow* on entrainment and salvage at both facilities.
Potential changes to routing of	No Action	No measurable change from current conditions, included under seasonal operations. Current trends will continue.
	Alternative 1	**Juvenile–Yearling and Emigration:** Beneficial impacts from *flow* on routing.

Impact	Alternative	Direction of Impacts
spring-run Chinook salmon	Alternative 2	**Juvenile–Yearling and Emigration:** Adverse or beneficial impacts from *flow* in the winter and spring, dependent on OMR grouping.
	Alternative 3	**Juvenile–Yearling and Emigration:** Adverse or beneficial impacts from *flow*, particularly under OMR -5,000.
	Alternative 4	**Juvenile–Yearling and Emigration:** Adverse or beneficial impacts from *flow* dependent on OMR grouping.
Potential changes to through Delta survival of spring-run Chinook salmon	No Action	No measurable change from current conditions, included under seasonal operations. Current trends are expected to continue.
	Alternative 1	**Juvenile–Yearling and Emigration:** Beneficial impacts from *flow* on routing. Negligible impacts on survival.
	Alternative 2	**Juvenile–Yearling and Emigration:** Adverse or beneficial impacts from *flow* on survival.
	Alternative 3	**Juvenile–Yearling and Emigration:** Adverse or beneficial impacts from *flow* on survival under certain OMR groupings.
	Alternative 4	**Juvenile–Yearling and Emigration:** Adverse or beneficial impacts from *flow* on survival.
CALIFORNIA CENTRAL VALLEY STEELHEAD DPS		
Sacramento River		
Potential changes to steelhead from seasonal operations	No Action	No measurable change from current operations expected. • **Beneficial Components:** Ramping Rates. • **Adverse and/or Beneficial Components:** Seasonal Operations and Rice Decomposition Smoothing, Water Temperature Management, Fall and Winter Refill and Redd Maintenance, and Spring Pulse Flows.
	Alternative 1	• **Spawning and Egg Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat area, and moderate beneficial impacts in critically dry water year types on redd dewatering potential. Beneficial impacts and some adverse impacts from *water temperatures* on spawning and egg incubation. Potential beneficial impacts to spawning behavior from removal of Spring Pulse Flows component. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on fry and juvenile rearing habitat area, adverse impacts on fry stranding during wetter water year types, and beneficial impacts on fry stranding during drier water year types. Beneficial impacts from *water temperatures* on juvenile rearing and emigration. Potential adverse impacts on juvenile outmigration and beneficial impacts on fry stranding from removal of Spring Pulse Flows component. • **Adult Upstream Migration and Holding:** Negligible adverse impacts from *flow* in the upper river but may have adverse impacts during peak migration of critically dry years. in the lower river. Adverse impacts from *water temperatures* on adult migration and holding. Potential adverse impact on adult migration from removal of Spring Pulse Flows component.

Impact	Alternative	Direction of Impacts
		• **Kelt Emigration:** Potential negligible adverse impacts from *flow*, as *flows* are expected to be above the minimum *flow* to avoid crowding and passage delays. Beneficial impacts from *water temperatures* on kelt emigration. Potential adverse impact on kelt emigration from removal of Spring Pulse Flows component.
	Alternative 2	• **Spawning and Egg Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat area, and generally beneficial impacts on redd dewatering potential. Potential adverse and beneficial impacts from *water temperatures* on spawning and egg incubation. Potential adverse impacts to spawning behavior from Spring Pulse Flows. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on fry and juvenile rearing habitat area. General beneficial impacts from *flow* on fry stranding, however, two phases of Alternative 2 (Without TUCP Delta VA and Without TUCP Systemwide VA) are expected to have adverse impacts in critically dry water year types. Beneficial and negligible adverse impacts from *water temperatures*. Spring Pulse Flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding. • **Adult Upstream Migration and Holding:** Negligible impacts from *flow* from impacts in the upper river but may have adverse and beneficial impacts during critically dry water year types in the lower river. Beneficial and negligible adverse impacts from *water temperatures*. Spring Pulse Flows may have a beneficial impact on adult migration. • **Kelt Emigration:** Potential negligible adverse impacts from *flow* change, as *flow*s are expected to be above the minimum *flow* to avoid crowding and passage delays. Beneficial impacts from *water temperatures*. Spring Pulse Flows may have a beneficial impact on kelt emigration.
	Alternative 3	• **Spawning and Egg Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat area, and adverse and beneficial impacts on redd dewatering potential. Frequent beneficial impacts and some adverse impacts from *water temperatures* on spawning and egg incubation. Potential adverse impacts to spawning behavior from Spring Pulse Flows. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flows* on fry and juvenile rearing habitat area, adverse impacts on fry stranding during above normal/below normal years and beneficial impacts in fry stranding during dry years. Frequent beneficial impacts and negligible adverse impacts from *water temperatures*. Spring Pulse Flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding.

Impact	Alternative	Direction of Impacts
		• **Adult Upstream Migration and Holding:** Negligible impacts from *flow* in the upper river but may have adverse and beneficial impacts during critically dry years in the lower river. Potential beneficial impacts and negligible adverse impacts from *water temperatures* on adult migration and holding. Spring Pulse Flows may have a beneficial impact on adult migration. • **Kelt Emigration:** Potential negligible adverse impacts from *flow* changes, as *flows* are expected to be above the minimum *flow* to avoid crowding and passage delays. Beneficial impacts and negligible adverse impacts from *water temperatures*. Spring Pulse Flows may have a beneficial impact on kelt emigration.
	Alternative 4	• **Spawning and Egg Incubation:** Negligible adverse impacts from *flow* on spawning habitat area, and beneficial impacts on redd dewatering potential during some water years. Beneficial impacts and adverse impacts from *water temperatures*. Potential adverse impacts to spawning behavior from Spring Pulse Flows. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow*s on fry and juvenile rearing habitat area, beneficial impacts on fry stranding with decreases during dry years. Beneficial impacts and negligible adverse impacts from *water temperatures*. Spring Pulse Flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding. • **Adult Upstream Migration and Holding:** Negligible adverse impacts from *flow* in the upper river but may have beneficial impacts during critically dry years in the lower river. Beneficial impacts and negligible adverse impacts from *water temperatures*. Spring Pulse Flows may have a beneficial impact on adult migration. • **Kelt Emigration:** Potential negligible impacts from *flow* change, as *flows* are expected to be above the minimum *flow* to avoid crowding and passage delays. Adverse and beneficial impacts from *water temperatures*. Spring Pulse Flows may have a beneficial impact on kelt emigration.
Clear Creek		
Potential changes to steelhead from seasonal operations	No Action	No measurable change from current operations and trends. • **Adverse:** Segregation Weir. • **Adverse and/or Beneficial:** Seasonal Operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Pulse Flows, Water Temperature Management, and Spawning and Rearing Habitat.

Impact	Alternative	Direction of Impacts
	Alternative 1	• **Spawning and Egg Incubation:** Adverse impacts from *flow* on spawning habitat across all water year types. Beneficial impacts from *water temperatures* on spawning and egg incubation. • **Juvenile Rearing and Emigration:** Adverse impacts from *flow*s on fry and juvenile rearing habitat area. Negligible adverse impacts from *water temperatures*. • **Adult Upstream Migration and Holding:** Adverse impacts from reductions in *flow* throughout the year. Negligible impacts from *water temperatures*. • **Kelt Emigration:** Adverse impacts from reductions in *flow* throughout the year. Negligible impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Beneficial impacts from *flow* on spawning habitat across all water year types. Potential negligible impacts from *water temperatures.* • **Juvenile Rearing and Emigration:** Negligible impacts from *flow* on fry rearing habitat and adverse impacts on juvenile rearing habitat. No anticipated impacts from *water temperatures*. • **Adult Upstream Migration and Holding:** Negligible impacts from *flow*. No anticipated impacts from *water temperatures*. • **Kelt Emigration:** Negligible impacts from *flow* and no anticipated impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial impacts from *flow* on spawning habitat. Negligible impacts from *water temperatures* on spawning and egg incubation. • **Juvenile Rearing and Emigration:** Negligible impacts from *flow* on fry rearing habitat and adverse impacts on juvenile rearing habitat. • **Adult Upstream Migration and Holding:** Negligible impacts from *flow*. • **Kelt Emigration:** Negligible impacts from *flow* and no anticipated impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Beneficial impacts from *flow* on spawning habitat. Similar adverse and beneficial impacts from *water temperatures* on spawning and egg incubation. • **Juvenile Rearing and Emigration:** Negligible impacts from *flow* on fry rearing habitat and adverse impacts on juvenile rearing habitat. No anticipated impacts from *water temperatures*. • **Adult Upstream Migration and Holding:** Negligible impacts from *flow*. No anticipated impacts from *water temperatures*. • **Kelt Emigration:** Negligible impacts from *flow* and no anticipated impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
Lower American River		
Potential changes to steelhead from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Pulse Flows, Redd Dewatering Adjustments, and Spawning and Rearing Habitat Restoration. • **Adverse and/or Beneficial:** Seasonal Operations and Water Temperature Management.
	Alternative 1	• **Spawning and Egg Incubation:** Adverse impacts from *flow* on spawning habitat area and adverse impacts on redd dewatering potential in drier water year types. Adverse impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse impacts from *flow* in critically dry water year types on rearing habitat area. Adverse and beneficial impacts from *water temperatures* on juvenile rearing and emigration. • **Adult Upstream Migration and Holding:** Negligible impacts from *flow* during peak adult migration and holding but there may be adverse impacts in September of drier water year types. Adverse and beneficial impacts from *water temperatures*. • **Kelt Emigration:** Negligible impacts from *flow* and *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Adverse impacts from *flow* on spawning habitat area and redd dewatering potential. Adverse and beneficial impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* in critically dry water year types on rearing habitat area depending on the month. Negligible adverse and beneficial impacts from *water temperatures*. • **Adult Upstream Migration and Holding:** Negligible impacts from *flow* during peak adult migration and holding but there may be adverse impacts in October and November of drier water year types. Adverse and beneficial impacts from *water temperatures* depending on the location (Hazel Ave or Watt Ave). • **Kelt Emigration:** Negligible impacts from *flow*. Adverse and beneficial impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Adverse or beneficial impacts from *flow* on spawning habitat area and are expected decrease redd dewatering potential. Adverse impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* in critically dry years on rearing habitat. Adverse impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
		• **Adult Upstream Migration and Holding:** Negligible impacts from *flow* during peak adult migration and holding. Adverse and beneficial impacts from *water temperatures* depending on the location (Hazel or Watt Ave). • **Kelt Emigration:** Negligible impacts from *flow*. Adverse and beneficial impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Adverse impacts from *flow* on spawning habitat area and adverse impacts on redd dewatering potential. Adverse impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse impacts from *flow* in critically dry waters on rearing habitat area. Beneficial and adverse impacts from *water temperatures*. • **Adult Upstream Migration and Holding:** Negligible impacts from *flow*. Beneficial and adverse impacts from *water temperatures* on adult migration and holding. • **Kelt Emigration:** Negligible impacts from *flow*. Adverse impacts from *water temperatures*.
Bay-Delta		
Potential changes to steelhead from seasonal operations	No Action	No measurable change from current operations. • **Adverse:** Agricultural Barriers. **Beneficial:** Spring Delta Outflow. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	**Juvenile Rearing and Emigration:** Possibly less *flow* into CVP under OMR -2,000 and -5,000; possibly less flow into HOR.
	Alternative 2	**Juvenile Rearing and Emigration:** Negligible impacts on *flow* into HOR. Phases without VA may have minimal less flow into CVP under OMR -2,000; phases with VA may have negligible impacts on flow into CVP. Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 3	**Juvenile Rearing and Emigration:** Possibly little to less *flow* into CVP under OMR -3,500. Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 4	**Juvenile Rearing and Emigration:** Possibly little to less *flow* into CVP under OMR -2,000. Impacts from pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
Potential changes to entrainment of steelhead	No Action	No measurable change from current conditions, continuation of current trends under the No Action Alternative. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, and Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	**Juvenile Rearing and Emigration:** Increases in entrainment.
	Alternative 2	**Juvenile Rearing and Emigration:** Increases and decreases in entrainment.

Impact	Alternative	Direction of Impacts
	Alternative 3	**Juvenile Rearing and Emigration:** Decreases in entrainment.
	Alternative 4	**Juvenile Rearing and Emigration:** Increases and decreases in entrainment.
Potential changes to routing and through Delta survival of steelhead	No Action	No measurable change from current conditions, included under seasonal operations.
	Alternative 1	**Juvenile Rearing and Emigration:** Beneficial impacts with a smaller proportion routed to Interior Delta between December and March, particularly in OMR bins more negative than -5,500.
	Alternative 2	**Juvenile Rearing and Emigration:** Adverse or beneficial impacts for outmigrating juvenile steelhead in the winter and spring, dependent on OMR grouping. Adverse or beneficial impacts on survival of outmigrating juvenile steelhead depending on OMR grouping.
	Alternative 3	**Juvenile Rearing and Emigration:** Adverse or beneficial impacts with a smaller proportion routed to Interior Delta between December and March, particularly under OMR -5,000. Potential adverse or beneficial impacts on survival of outmigrating juvenile steelhead, under certain OMR conditions.
	Alternative 4	**Juvenile Rearing and Emigration:** Adverse or beneficial impacts from *flow* dependent on OMR grouping.
San Joaquin River		
Potential changes to steelhead from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	• **Juvenile Rearing and Emigration:** Negligible impacts from *flow* and *water temperatures* on juvenile emigration. • **Adult Upstream Migration and Holding:** Negligible to minor beneficial impacts from *flow* and *water temperatures*.
	Alternative 2	• **Juvenile Rearing and Emigration:** Negligible impacts from *flow* and *water temperatures* on juvenile emigration. • **Adult Upstream Migration and Holding:** Beneficial impacts from *flow* and *water temperatures*.
	Alternative 3	• **Juvenile Rearing and Emigration:** Negligible impacts from *flow* and *water temperatures* on juvenile emigration. • **Adult Upstream Migration and Holding:** Adverse impacts from *flow* and *water temperatures*.
	Alternative 4	• **Juvenile Rearing and Emigration:** Negligible impacts from *flow* and *water temperatures* on juvenile emigration. • **Adult Upstream Migration and Holding:** Potential beneficial impacts from *flow* and *water temperatures*.

Impact	Alternative	Direction of Impacts
Stanislaus River		
Potential changes to steelhead from seasonal operations	No Action	No measurable change from current conditions, continuation of current trends under the No Action Alternative. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Winter Instability Flows, Spring Pulse Flows, Fall Pulse Flows, Spawning, and Rearing Habitat Restoration. • **Adverse/and or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Adverse impacts from *flow* on spawning habitat area. Potential beneficial impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse or beneficial impacts from *flow* on juvenile and fry rearing habitat area depending on the water year type and may decrease depending on the month. Potential beneficial impacts from *water temperatures* on juvenile emigration. • **Adult Upstream Migration and Holding:** Potential adverse and beneficial impacts from *flow* during critically dry water year types. Potential negligible impacts from *water temperatures*. • **Kelt Emigration:** Potential beneficial impacts from *flow* during critically dry years. Potential beneficial impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat area, depending on the water year type. Potential negligible adverse impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on juvenile and fry rearing habitat area depending on the water year type. Potential negligible adverse impacts from *water temperatures* on juvenile emigration. • **Adult Upstream Migration and Holding:** Potential beneficial impacts from *flow* in the fall of drier years. Potential negligible impacts from *water temperatures*. • **Kelt Emigration:** Potential beneficial impacts from *flow* in February of drier years. Potential adverse impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Adverse impacts from *flow* on spawning habitat area in wet, below normal, and dry water year types. Potential beneficial impacts from *water temperatures* on spawning and egg incubation. • **Juvenile Rearing and Emigration:** Adverse or beneficial impacts from *flow* on juvenile and fry rearing habitat area depending on the water year type. Potential beneficial impacts from *water temperatures* on juvenile emigration. • **Adult Upstream Migration and Holding:** Potential adverse impacts from *flow* in September, November, December of drier water year types. Potential negligible impacts from *water temperatures* on adult migration and holding.

Impact	Alternative	Direction of Impacts
		• **Kelt Emigration:** Potential beneficial impacts from *flow* in February of drier years. Potential beneficial impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Adverse or beneficial impacts from *flow* on spawning habitat area depending on water year type. Potential negligible impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse or beneficial impacts from *flow* on juvenile and fry rearing habitat area depending on the water years. Potential negligible impacts from *water temperatures* on juvenile emigration. • **Adult Upstream Migration and Holding:** Potential beneficial impacts from *flow* in the fall of drier years. Potential negligible impacts from *water temperatures* on adult migration and holding. • **Kelt Emigration:** Potential beneficial impacts from changes in *flow* in February of drier years. Potential adverse impacts from *water temperatures*.
SOUTHERN DPS GREEN STURGEON		
Sacramento River		
Potential changes to green sturgeon from seasonal operations	No Action	No measurable change from current operations. • **Adverse and/or Beneficial Components:** Seasonal Operations and Fall and Winter Refill and Redd Maintenance. • **Adverse Components:** Rice Decomposition Smoothing. • **Beneficial Components:** Ramping Rates, Spring Pulse Flows, Water Temperature Management.
	Alternative 1	• **Spawning and Egg Incubation:** Potential adverse impacts from *flow* on spawning and incubation habitat. Beneficial impacts from *water temperatures* on spawning and egg incubation. • **Larval and Juvenile Rearing and Emigration:** Potential adverse impacts from *flow* on rearing and emigration. Adverse and beneficial impacts from *water temperatures*. • **Adult Upstream Migration and Holding:** Possible adverse impacts from *flow* on upstream migration and holding habitats. Adverse and beneficial impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** No impacts to possible beneficial impacts from *flow* on spawning habitat depending on phase, location, month, and water year type. Beneficial impacts and minor adverse impacts from *water temperatures* on spawning and egg incubation depending on location, month, and water year type. • **Larval and Juvenile Rearing and Emigration:** Minor adverse impacts from *flow* are expected on rearing and emigration depending on phase, location, month, and water year type. Adverse and beneficial impacts from *water temperatures* are expected depending on phase, location, month, and water year type.

Impact	Alternative	Direction of Impacts
		• **Adult Upstream Migration and Holding:** Adverse and beneficial impacts from *flow* on upstream migration and holding habitats depending on phase, location, month, and water year type. Adverse impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat. Beneficial and adverse impacts from *water temperatures*. • **Larval and Juvenile Rearing and Emigration:** Adverse impacts from *flow* are expected on rearing and emigration. Adverse and beneficial impacts from *water temperatures*. • **Adult Upstream Migration and Holding:** Adverse and beneficial impacts from *flow* on upstream migration and holding habitats. Negligible adverse and beneficial impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Adverse and beneficial impacts from *water temperatures*. • **Larval and Juvenile Rearing and Emigration:** Beneficial impacts from *flow*. Adverse and beneficial impacts from *water temperatures*. • **Adult Upstream Migration and Holding:** No impacts to beneficial impacts from *flow*. Adverse impacts from *water temperatures* on upstream migration and holding depending on location, month, and water year type.
San Joaquin River		
Potential changes to green sturgeon from seasonal operations	No Action	No measurable change from current operations and trends.
	Alternative 1	**Adults:** Beneficial impacts from *flow*
	Alternative 2	**Adults:** Beneficial impacts from *flow*
	Alternative 3	**Adults:** No impacts from *flow*.
	Alternative 4	**Adults:** Beneficial impacts from *flow*.
Bay-Delta		
Potential changes to green sturgeon from seasonal operations	No Action	No change from current operations. • **Adverse:** Seasonal Operations and Agricultural Barriers.
	Alternative 1	• **Juvenile Rearing and Emigration:** No impacts from *flow* on year class strength. • **Adult Upstream Migration and Holding:** No impacts from *flow*
	Alternative 2	• **Juvenile Rearing and Emigration:** No impacts from *flow* on year class strength. • **Adult Upstream Migration and Holding:** No impacts from *flow* on adult migration.
	Alternative 3	• **Juvenile Rearing and Emigration:** Beneficial impacts from *flows* on year class strength. • **Adult Upstream Migration and Holding:** Beneficial impacts from *flow* on adult migration.

Impact	Alternative	Direction of Impacts
	Alternative 4	• **Juvenile Rearing and Emigration:** No impacts from *flow* on year class strength. • **Adult Upstream Migration and Holding:** No impacts from *flow* on adult migration.
Potential changes to entrainment of green sturgeon	No Action	No measurable change from current conditions, continuation of current trends under the No Action Alternative. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	**Juvenile Rearing and Emigration:** Potential adverse impacts but since salvaged so rarely, numbers may not be representative.
	Alternative 2	**Juvenile Rearing and Emigration:** Potential beneficial impacts but since salvaged so rarely, numbers may not be representative.
	Alternative 3	**Juvenile Rearing and Emigration:** Potential beneficial impacts but since salvaged so rarely, numbers may not be representative.
	Alternative 4	**Juvenile Rearing and Emigration:** Potential beneficial and adverse impacts but since salvaged so rarely, numbers may not be representative.
DELTA SMELT		
Bay-Delta		
Potential changes to Delta smelt from seasonal operations	No Action	No measurable change from current operations. • **Adverse Components:** Seasonal Operations. • **Beneficial Components:** Spring Delta Outflow, Delta Smelt Supplementation, and Delta Smelt SFH.
	Alternative 1	• **Adults:** Adverse impacts from *flow* on prey abundance (CPUE) and population growth rates. Negligible impacts on low salinity habitat (i.e., X2 position). • **Eggs and Larvae:** Adverse impacts from *flow* on prey abundance (CPUE) and population growth rates. Negligible impacts on low salinity habitat (i.e., X2 position). • **Juveniles:** Potential adverse impacts from *flow* on prey abundance (CPUE), and population growth rates. Potential impacts on low salinity habitat. Potential adverse impacts on suitable summer and fall habitat.
	Alternative 2	• **Adults:** Adverse impacts from *flow* on prey abundance (CPUE), and population growth rates. Negligible impacts on low salinity habitat (i.e., X2 position). • **Eggs and Larvae:** Adverse to beneficial impacts from *flow* on prey abundance (CPUE), and population growth rates. Negligible impacts on low salinity habitat (i.e., X2 position).

Impact	Alternative	Direction of Impacts
		• **Juveniles:** Adverse impacts from *flow* on prey abundance (CPUE), and population growth rates. Negligible impacts on low salinity habitat (i.e., X2 position). Negligible to minor beneficial and minor adverse impacts on suitable summer and fall habitat depending on water year type and application of temperature threshold.
	Alternative 3	• **Adults:** Beneficial impacts from *flow* on prey abundance (CPUE), and population growth rates. Negligible to beneficial impacts on low salinity habitat (i.e., X2 position). • **Eggs and Larvae:** Beneficial impacts from *flow* on prey abundance (CPUE), and population growth rates. Negligible to beneficial impacts on low salinity habitat (i.e., X2 position). • **Juveniles:** Beneficial impacts from *flow* on prey abundance (CPUE), and population growth rates. Negligible on low salinity habitat (i.e., X2 position). Beneficial and adverse impacts on suitable summer and fall habitat
	Alternative 4	• **Adults:** Adverse impacts from *flow* on prey abundance (CPUE), and population growth rates. Negligible impacts on low salinity habitat (i.e., X2 position). • **Eggs and Larvae:** Adverse impacts from *flow* on prey abundance (CPUE), and population growth rates. Negligible impacts on low salinity habitat (i.e., X2 position). • **Juveniles:** Adverse impacts from *flow* on prey abundance (CPUE), and population growth rates. Adverse impacts on low salinity habitat (i.e., X2 position). Adverse impacts on suitable summer and fall habitat.
Potential changes to entrainment of Delta smelt	No Action	No measurable change from current conditions, continuation of current trends. • **Adverse:** RRDS Fall Flood-up. • **Beneficial:** BSPP, Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** Tracy Fish Collection Facility and John E. Skinner Fish Protective Facility.
	Alternative 1	• **Adults:** Adverse impacts from *flow*, OMR values were more negative from January to June. • **Eggs and Larvae:** Possible adverse to beneficial impacts from *flow* on larvae depending on particle origin, inflow grouping, and OMR grouping. • **Juveniles:** Adverse to beneficial impacts from *flow*, in general, OMR values were more negative in June, September and October and less negative in November.
	Alternative 2	• **Adults:** Adverse to beneficial impacts from *flow*, OMR values were more negative during April and May for phases without VAs and May for phases with VAs. OMR values were less negative during June for phases without VAs, March and June for the Delta VA phase and March, April and June for the phase with systemwide VAs.

Impact	Alternative	Direction of Impacts
		• **Eggs and Larvae:** Beneficial to adverse impacts from *flow* based on inflow grouping and OMR grouping. • **Juveniles:** Negligible to beneficial impacts from *flow*, OMR was less negative across all phases in June.
	Alternative 3	• **Adults:** Beneficial impacts from *flow*, OMR values were less negative from January to June • **Eggs and Larvae:** Beneficial impacts from *flow* for all inflow grouping. Negligible impacts from *flow* based on OMR groupings. • **Juveniles:** Beneficial impacts from *flow*, OMR values were less negative from June to November.
	Alternative 4	• **Adults:** Adverse to beneficial impacts from *flow*, OMR values were less negative from January and June but more negative from February to May. • **Eggs and Larvae:** Potential adverse tonegligible impacts from *flow* based on inflow grouping and OMR grouping. • **Juveniles:** Negligible to beneficial impacts from *flow*, OMR values were less negative in June.
LONGFIN SMELT		
Bay-Delta		
Potential changes to Longfin smelt from seasonal operations	No Action	No measurable change from current operations. • **Adverse Components:** Seasonal Operations. • **Beneficial Components:** Spring Delta Outflow, and Delta Smelt SFH.
	Alternative 1	• **Adults:** Adverse impacts from *flow* on prey abundance (CPUE). Negligible impacts on low salinity habitat (i.e., X2 position) in winter and spring, adverse impacts during wet and above normal years in fall (September and October). • **Eggs and Larvae:** Adverse and beneficial impacts from *flow* on prey abundance (CPUE), depending on water year type and season. Negligible impacts on low salinity habitat (i.e., X2 position). • **Juveniles:** Adverse impacts from *flow* on prey abundance (CPUE), and juvenile abundance. Negligible impacts on low salinity habitat (i.e., X2 position).
	Alternative 2	• **Adults:** Beneficial and adverse impacts from *flow* on prey abundance (CPUE). Negligible impacts on low salinity habitat (i.e., X2 position). • **Eggs and Larvae:** Adverse and beneficial impacts from *flow* on prey abundance (CPUE). Negligible impacts on low salinity habitat (i.e., X2 position). • **Juveniles:** Beneficial and adverse impacts from *flow* on juvenile abundance and prey abundance (CPUE). Negligible impacts on low salinity habitat (i.e., X2 position).

Impact	Alternative	Direction of Impacts
	Alternative 3	• **Adults:** Beneficial impacts from *flow* on prey abundance (CPUE) and negligible to beneficial impacts on low salinity habitat (i.e., X2 position). • **Eggs and Larvae:** Beneficial impacts from *flow* on prey abundance (CPUE) and negligible to beneficial impacts on low salinity habitat (i.e., X2 position). • **Juveniles:** Beneficial impacts from *flow* on juvenile abundance and prey abundance (CPUE) and negligible to beneficial impacts on low salinity habitat (i.e., X2 position).
	Alternative 4	• **Adults:** Negligible to beneficial and adverse impacts from *flow* on prey abundance (CPUE) depending on water year type. Negligible impacts on low salinity habitat (i.e., X2 position). • **Eggs and Larvae:** Negligible to beneficial and adverse impacts from *flow* on prey abundance (CPUE) depending on water year type. Negligible impacts on low salinity habitat (i.e., X2 position). • **Juveniles:** Negligible impacts from *flow* on juvenile abundance and negligible to adverse impacts on prey abundance (CPUE). Negligible impacts on low salinity habitat (i.e., X2 position).
Potential changes to entrainment of Longfin smelt	No Action	No measurable change from current conditions, continuation of current trends. • **Adverse:** RRDS Fall Flood-up. • **Beneficial:** BSPP, and Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility.
	Alternative 1	• **Adults:** Negligible impacts from *flow* on X2 position in winter and spring, adverse impacts during wet and above normal years in fall (September and October). Adverse impacts from increased exports and more negative OMR values that were greater than -5000 cfs during the winter. • **Eggs and Larvae:** Potential negligible to adverse impacts from *flow* for inflow groupings and OMR groupings. • **Juveniles:** Adverse impacts from *flow*, particularly in above normal water year type.
	Alternative 2	• **Adults:** Negligible impacts from *flow* on X2 position. Adverse impacts from higher exports and more negative OMR values for phases without VAs and beneficial impacts from lower exports and less negative OMR values for phases with VAs. • **Eggs and Larvae:** Negligible to beneficial impacts from *flow* depending on particle origin, inflow grouping, and OMR grouping. • **Juveniles:** Adverse impacts from *flow* under all phases of Alternative 2 in all water year types except a dry water year type under Alternative 2 without TUCP Systemwide VA, which is expected to have beneficial impacts.

Impact	Alternative	Direction of Impacts
	Alternative 3	• **Adults:** Negligible to beneficial impacts from *flow* on X2 position, moving X2 further seaward for most months and water year types. Beneficial impacts from decreased exports and less negative OMR values. • **Eggs and Larvae:** Beneficial impacts from *flow* based on inflow grouping. Possible negligible to beneficial impacts from *flow* depending on OMR grouping. • **Juveniles:** Beneficial impacts from *flow*.
	Alternative 4	• **Adults:** Negligible impacts from *flow* on X2 position. Adverse and beneficial impacts from exports and OMR values depending on month. • **Eggs and Larvae:** Possible negligible impacts from *flow* depending on inflow grouping and OMR grouping. • **Juveniles:** Adverse impacts from *flow*.
FALL-RUN AND LATE FALL-RUN CHINOOK SALMON ESU		
Sacramento River		
Potential changes to fall-run and late fall-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations. • **Beneficial Components:** Ramping Rates and Water Temperature Management. • **Adverse and/or Beneficial Components:** Seasonal Operations and Rice Decomposition Smoothing, Fall and Winter Refill and Redd Maintenance, and Spring Pulse Flows.
	Alternative 1	• **Fall-run Spawning and Egg/Alevin Incubation:** Beneficial impacts from *flow* on spawning habitat area and redd dewatering potential. Adverse impacts from *water temperatures* on spawning initiation. • **Fall-run Juvenile Rearing and Emigration:** Adverse impacts from *flow* on rearing habitat. Adverse and beneficial impacts from *flow* on fry stranding, depending on water year type. Adverse impacts from *water temperatures* on growth and smoltification and beneficial impacts on pathogen virulence. Potential adverse impacts on juvenile outmigration and beneficial impacts on fry stranding from removal of Spring Pulse Flows component. • **Fall-run Adult Migration and Holding:** Adverse impacts from *water temperatures* on adult migration and pathogen virulence. • **Late Fall-run Spawning and Egg/ Alevin Incubation:** Adverse impacts from *flow* on spawning habitat. Adverse impacts from *water temperatures* on spawning and incubation and the frequency of pathogen virulence. Potential beneficial impacts to spawning behavior from removal of Spring Pulse Flows component. • **Late Fall-run Juvenile Rearing and Emigration:** Adverse impacts from *flow* on fry and juvenile rearing habitat. Adverse and beneficial impacts from *water temperatures* on conditions for growth, smoltification, vulnerability to predators and virulent pathogens. Potential adverse impacts on juvenile outmigration and beneficial impacts on fry stranding from removal of Spring Pulse Flows component.

Impact	Alternative	Direction of Impacts
	Alternative 2	• **Fall-run Spawning and Egg/Alevin Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat and redd dewatering potential. Adverse impacts from *water temperatures* on spawning initiation below Keswick Dam. • **Fall-run Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on fry and juvenile rearing habitat, and adverse and beneficial impacts on fry stranding, however the beneficial impacts are greater and more frequent. Adverse and beneficial impacts from *water temperatures* on juvenile rearing and emigration. Spring pulse flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding. • **Fall-run Adult Migration and Holding:** Beneficial impacts from *water temperatures* on adult migration and holding. • **Late Fall-run Spawning and Egg/Alevin Incubation:** Negligible adverse impacts from *flow* on spawning habitat area and impact redd dewatering potential. Beneficial impacts from *water temperatures* on incubation and fry emergence. Potential adverse impacts to spawning behavior from spring pulse flows. • **Late Fall-run Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on fry and juvenile rearing habitat area and fry stranding. Adverse and beneficial impacts from *water temperatures* on conditions for growth, smoltification, and vulnerability to predators, and beneficial impacts for juveniles with regards to pathogen virulence. Spring pulse flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding. • **Late Fall-run Adult Migration and Holding:** Beneficial impacts on juveniles with regards to pathogen virulence.
	Alternative 3	• **Fall-run Spawning and Egg/Alevin Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat and redd dewatering potential. • **Fall-run Juvenile Rearing and Emigration:** Adverse impacts from *flow* on fry rearing habitat, adverse and beneficial impacts on juvenile rearing habitat. Some adverse impacts on fry stranding in above normal years. Adverse impacts from *water temperatures* on growth, smoltification and predation, but beneficial impacts on juveniles in regards to pathogen virulence. Spring pulse flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding. • **Fall-run Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on adult migration and holding. Beneficial impacts from *water temperatures* on adult migration and pathogen virulence.

Impact	Alternative	Direction of Impacts
		• **Late Fall-run Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat area in above normal water years. Minor adverse impacts from on redd dewatering potential. Beneficial impacts from *water temperatures* on spawning initiation, egg incubation and fry emergence. Potential adverse impacts to spawning behavior from spring pulse flows. • **Late Fall-run Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on fry and juvenile rearing habitat, and adverse impacts on fry stranding. Adverse impacts from *water temperatures* on growth, smoltification, predation except at Hamilton City, where beneficial impacts are predicted. Beneficial impacts on juveniles in regard to pathogen virulence, except at Hamilton City where adverse impacts are predicted. Spring pulse flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding. • **Late Fall-run Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on adult migration and holding conditions. Beneficial impacts from *water temperatures* on migration and pathogen virulence.
	Alternative 4	• **Fall-run Spawning and Egg/Alevin Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat area. Adverse impacts from *flow* on redd dewatering potential in critically dry water years. • **Fall-run Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on fry and juvenile rearing habitat, and beneficial impacts on fry stranding. Adverse and beneficial impacts from *water temperatures*. Spring pulse flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding. • **Fall-run Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on adult migration and holding. Beneficial impacts from *water temperatures* on migration and pathogen virulence. • **Late Fall-run Spawning and Egg/ Alevin Incubation:** Adverse and beneficial impacts from *flow* on spawning habitat. Potential adverse impacts to spawning behavior from spring pulse flows. • **Late Fall-run Juvenile Rearing and Emigration:** Adverse impacts from *flow* on fry and juvenile rearing habitat and fry stranding. Adverse and beneficial impacts from *water temperatures*.. Spring pulse flows may have beneficial impacts on juvenile outmigration and adverse impacts on fry stranding. • **Late Fall-run Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on adult migration and holding conditions. Beneficial impacts from *water temperatures* on migration and pathogen virulence.

Impact	Alternative	Direction of Impacts
Clear Creek		

Potential changes to fall-run and late fall-run Chinook salmon from seasonal operations	No Action	No expected change from current operations.
		• **Fall-run**
		  • *Beneficial:* Ramping Rates, Minimum Instream Flows, Pulse Flows, Water Temperature Management, and Spawning and Rearing Habitat.
		  • *Adverse and/or Beneficial:* Summer and Fall Operations and Segregation Weir.
		• **Late Fall-run**
		  • *Beneficial:* Ramping Rates, Minimum Instream Flows, Pulse Flows, Water Temperature Management, and Spawning and Rearing Habitat,
		  • *Adverse and/or Beneficial:* Summer and Fall Operations.

	Alternative 1	• **Fall-run Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat. Negligible impacts from *water temperatures* on egg incubation, spawning initiation, pathogen virulence, and incubation/emergence. • **Fall-run Juvenile Rearing and Emigration:** Beneficial impacts from *flow* on fry but an adverse impact on juvenile rearing habitat. • **Fall-run Adult Migration and Holding:** Adverse impacts from decreased *flow*. • **Late Fall-run Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat. Negligible impacts from *water temperatures* on egg incubation, spawning initiation, pathogen virulence, and incubation/emergence. • **Late Fall-run Juvenile Rearing and Emigration:** Adverse impacts from *flow* on juvenile rearing habitat. • **Late Fall-run Adult Migration and Holding:** Adverse impacts from *flow*.
	Alternative 2	• **Fall-run Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat. • **Fall-run Juvenile Rearing and Emigration:** Beneficial impacts from *flow* on fry but adverse impacts on juvenile rearing habitat. • **Fall-run Adult Migration and Holding:** Adverse impacts from decreased *flow*. • **Late Fall-run Spawning and Egg/Alevin Incubation:** Adverse to beneficial impacts from *flow* on spawning habitat. No anticipated impact from *water temperatures*. • **Late Fall-run Juvenile Rearing and Emigration:** Adverse to beneficial impacts from *flow*. • **Late Fall-run Adult Migration and Holding:** Beneficial impacts from *flow*.
	Alternative 3	• **Fall-run Spawning and Egg/Alevin Incubation:** Beneficial impacts from *flow* in critically dry years and below normal years, but a negligible impact in all other water years

Impact	Alternative	Direction of Impacts
		• **Fall-run Juvenile Rearing and Emigration:** Decrease from *flow* on fry and juvenile rearing habitat. • **Fall-run Adult Migration and Holding:** Negative and beneficial impacts from decreased *flow* in July through October and increased flow in November and January. • **Late Fall-run Spawning and Egg/Alevin Incubation:** Adverse impacts and minor to moderate beneficial impacts from *flow* on spawning habitat. • **Late Fall-run Juvenile Rearing and Emigration:** Adverse impacts and beneficial impacts from *flow*. • **Late Fall-run Adult Migration and Holding:** Beneficial impacts from *flow*.
	Alternative 4	• **Fall-run Spawning and Egg/Alevin Incubation:** Beneficial impacts from *flow* on spawning habitat. No anticipated impacts from *water temperatures* on spawning and egg incubation. • **Fall-run Juvenile Rearing and Emigration:** Adverse impacts from *flow* on fry rearing and emigration habitat and juvenile rearing habitat. • **Fall-run Adult Migration and Holding:** Adverse and beneficial impacts from *flow*. • **Late Fall-run Spawning and Egg/Alevin Incubation:** Beneficial and adverse impacts from *flow* on spawning habitat. • **Late Fall-run Juvenile Rearing and Emigration:** Beneficial and adverse impacts from *flow*. • **Late Fall-run Adult Migration and Holding:** Beneficial impacts from *flow*.
Lower American River		
Potential changes to fall-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Spring Pulse Flows, Redd Dewatering Adjustments, Water Temperature Management, and Spawning and Rearing Habitat Restoration. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg/Alevin Incubation:** Adverse impact on spawning habitat and redd dewatering potential from *flow*. Adverse and beneficial impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse impacts from *flow* in below normal and dry years, but beneficial impacts from *flow* in critically dry years. Adverse and beneficial impacts from *water temperatures* on growth, smoltification, and predation vulnerability, and adverse impacts on pathogen virulence. • **Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on adult migration. Adverse and beneficial impacts from *water temperatures* on growth, smoltification, and predation vulnerability. Adverse impacts on pathogen virulence.

Impact	Alternative	Direction of Impacts
	Alternative 2	• **Spawning and Egg/Alevin Incubation:** Adverse impacts from *flow* on spawning habitat and increase in redd dewatering potential. Negligible impacts from *water temperatures.* • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow*. Adverse and beneficial impacts from *water temperatures*. • **Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on upstream migration. Adverse and beneficial impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg/Alevin Incubation:** Adverse and beneficial impact from *flow* on spawning habitat. Beneficial impacts from *flow* on redd dewatering potential. Adverse and beneficial impacts from *water temperatures* on spawning initiation, pathogen virulence, and egg incubation and fry emergence. • **Juvenile Rearing and Emigration:** Adverse impacts from *flow* in June and July. Adverse and beneficial impacts from *water temperatures* on spawning initiation, pathogen virulence, and egg incubation and fry emergence. • **Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on adult migration. Adverse and beneficial impacts from *water temperatures* on migration, and adverse impacts on pathogen virulence.
	Alternative 4	• **Spawning and Egg/Alevin Incubation:** Adverse impact from *flow* on spawning habitat area and redd dewatering potential in non-critically dry water years. Beneficial impact from *flow* on redd dewatering potential during critically dry years. Adverse and beneficial impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* during critically dry years. Adverse and beneficial impacts from *water temperatures*. • **Adult Migration and Holding:** Adverse and beneficial impacts from *flow* during critically dry years. Adverse and beneficial impacts from *water temperatures* on adult migration and pathogen virulence.
San Joaquin River		
Potential changes to fall-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	**Migration:** Adverse impacts from *flow* on migrating adults and beneficial impacts on migrating juveniles. Negligible impacts from *water temperatures*.
	Alternative 2	**Migration:** Negligible impacts from *water temperatures*.
	Alternative 3	**Migration:** Adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	**Migration:** Minimal impacts from *flow* on migrating adults and juveniles. Negligible impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
Bay-Delta		

Potential changes to fall-run and late fall-run Chinook salmon from seasonal operations	No Action	No measurable change from current operations.
		• **Fall-run:**
		  • *Adverse:* Agricultural Barriers.
		  • *Beneficial:* Spring Delta Outflow
		  • *Adverse and/or Beneficial:* Seasonal Operations.
		• **Late Fall-run:**
		  • *Beneficial:* Spring Delta Outflow.
		  • *Adverse and/or Beneficial:* Seasonal Operations.

	Alternative 1	**Juvenile–Yearling Rearing and Emigration:** Possibly less flow into CVP under OMR -2,000 and -5,000; possibly less flow into HOR. Impacts of pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 2	**Juvenile–Yearling Rearing and Emigration:** Negligible impacts on *flow* into HOR. Alternatives without VA may have minimal less flow into CVP under OMR -2,000; alternatives with VA may have negligible impacts on flow into CVP. Impacts of pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 3	**Juvenile–Yearling Rearing and Emigration:** Less flow into CVP under OMR -3,500; no change in flow into HOR. Impacts of pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
	Alternative 4	**Juvenile–Yearling Rearing and Emigration:** Less *flow* into CVP under OMR -2,000; no change in flow into HOR. Impacts of pumping smaller at more upstream locations (e.g., Jersey Point) and greater at Turner Cut.
Potential changes to entrainment of fall-run and late fall-run Chinook salmon	No Action	No measurable change from current conditions, continuation of current trends. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility.
	Alternative 1	**Fall-run / Late Fall-run Rearing and Emigration:** Adverse impacts from exports on the entrainment of the juvenile fall-run and late fall-run Chinook in the Delta at both fish facilities.
	Alternative 2	**Fall-run Rearing and Emigration:** Adverse impacts from exports on entrainment at Banks Pumping Plant under all phases, Adverse impacts on entrainment at the Jones Pumping Plant in Critically Dry years.
	Alternative 3	• **Fall-run Rearing and Emigration:** Adverse impacts from exports on entrainment at Banks and Jones Pumping Plants. • **Late Fall-run Rearing and Emigration:** Adverse impacts on entrainment at both Banks and Jones Pumping Plants.
	Alternative 4	• **Fall-run Rearing and Emigration:** Adverse impacts from exports on entrainment at Banks Pumping Plant.

Impact	Alternative	Direction of Impacts
		• **Late Fall-run Rearing and Emigration:** Adverse and beneficial impacts from exports on entrainment at Banks Pumping Plant.
Potential changes to through Delta survival of fall-run and late fall-run Chinook salmon	No Action	No measurable change from current conditions included under seasonal operations.
	Alternative 1	**Fall-run / Late Fall-run Rearing and Emigration:** Negligible impacts on through Delta survival.
	Alternative 2	**Fall-run / Late Fall-run Rearing and Emigration:** Negligible impacts on through Delta survival.
	Alternative 3	**Fall-run / Late Fall-run Rearing and Emigration:** Similar to No Action on through Delta survival.
	Alternative 4	**Fall-run / Late Fall-run Rearing and Emigration:** Negligible impacts on through Delta survival.
Stanislaus River		
Potential changes to fall-run Chinook salmon from seasonal operations	No Action	No change from current operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Winter Instability Flows, Spring Pulse Flows, Fall Pulse Flows, and Spawning and Rearing Habitat Restoration. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg/Alevin Incubation:** Beneficial impacts from *flow* on spawning habitat. Adverse impacts from *water temperatures* on spawning initiation and spawning pathogen virulence. • **Juvenile Rearing and Emigration:** Beneficial impacts from *flow*. Adverse and beneficial impacts from *water temperatures* on growth, smoltification and predation vulnerability, adverse impacts on pathogen virulence. • **Adult Migration and Holding:** Adverse impacts and beneficial impacts on adult migration. Beneficial impacts from *water temperatures* on migration, but adverse impacts on pathogen virulence.
	Alternative 2	• **Spawning and Egg/Alevin Incubation:** Beneficial impacts from *flow* on spawning habitat area. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on rearing habitat area. • **Adult Migration and Holding:** Adverse and beneficial impacts from *flow* on adult migration.
	Alternative 3	• **Spawning and Egg/Alevin Incubation:** Negligible adverse and beneficial impacts from *flow* on spawning habitat area. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on rearing habitat area. • **Adult Migration and Holding:** Adverse impacts from *flow* on adult migration. Adverse impacts from *water temperatures* on growth, smoltification, predation vulnerability and pathogen virulence.

Impact	Alternative	Direction of Impacts
	Alternative 4	• **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* on rearing habitat area. Beneficial impacts from *water temperatures* on growth, smoltification, predation vulnerability and pathogen virulence. • **Adult Migration and Holding:** Negligible adverse impacts and beneficial impacts from *flow* on adult migration.
WHITE STURGEON		
Sacramento River		
Potential changes to white sturgeon from seasonal operations	No Action	No measurable change from current operations. • **Adverse Components:** Fall and Winter Refill and Redd Maintenance. • **Beneficial Components:** Ramping Rates, Spring Pulse Flows, Water Temperature Management. • **Adverse and/or Beneficial Components:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Potential beneficial impacts from *flow* on spawning habitat. Possible beneficial impacts from *water temperatures*. • **Rearing and Emigration:** Potential beneficial impacts from *flow* on rearing and emigration habitat. Beneficial impacts from *water temperatures* on rearing and emigration.
	Alternative 2	**Spawning and Egg Incubation:** Potential beneficial impacts from *flow* on spawning habitat.
	Alternative 3	**Spawning and Egg Incubation:** Potential beneficial impacts from *flow* on spawning habitat. Adverse impacts from *water temperatures*.
	Alternative 4	**Rearing and Emigration:** Potential adverse impacts from *flow*.
Lower American River		
Potential changes to white sturgeon from seasonal operations	No Action	No measurable change from current operations. • **Adverse and Beneficial:** Seasonal Operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Spring Pulse Flows, Redd Dewatering Adjustments, Water Temperature Management, and Spawning and Rearing Habitat Restoration.
	Alternative 1	**Adult White Sturgeon:** No impacts from *flow* and *water temperatures*.
	Alternative 2	**Adult White Sturgeon:** No impacts from *flow* and *water temperatures*.
	Alternative 3	**Adult White Sturgeon:** No impacts from *flow* and *water temperatures*.
	Alternative 4	**Adult White Sturgeon:** Negligible impacts from *water temperatures*.
San Joaquin River		
Potential changes to white sturgeon from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	**Adult White Sturgeon:** Negligible impacts from *water temperatures*.
	Alternative 2	**Adult White Sturgeon:** Negligible impacts from *water temperatures*.
	Alternative 3	**Adult White Sturgeon:** Potential adverse impacts from *flow* on habitat. Negligible impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
	Alternative 4	**Adult White Sturgeon:** Negligible impacts from *water temperatures*.
Bay-Delta		
Potential changes to white sturgeon from seasonal operations	No Action	No measurable change from current operations. • **Adverse:** Agricultural Barriers, RRDS Fall Flood-up. • **Beneficial:** Spring Delta Outflow • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Juvenile Rearing and Emigration:** Potential beneficial impacts from *flow* on juvenile year class strength. • **Subadult and Adult Residency:** Potential beneficial impacts on year class strength.
	Alternative 2	• **Juvenile Rearing and Emigration:** Potential beneficial impacts from *flow* on juvenile year class strength. • **Subadult and Adult Residency:** Potential beneficial impacts from *flow* on year class strength.
	Alternative 3	• **Juvenile Rearing and Emigration:** Potential beneficial impacts from *flow* on juvenile year class strength. • **Subadult and Adult Residency:** Possible beneficial impacts from *flow* on year class strength.
	Alternative 4	• **Juvenile Rearing and Emigration:** No impacts from *flow* on juvenile year class strength. • Subadult and Adult Residency: No impacts from *flow* on year class strength.
Potential changes to entrainment of white sturgeon	No Action	No measurable change from current conditions, continuation of current trends. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility.
	Alternative 1	• **Juvenile Rearing and Emigration:** No impacts from exports on juvenile entrainment.
	Alternative 2	• **Juvenile Rearing and Emigration:** No impacts from exports on juvenile entrainment.
	Alternative 3	• **Juvenile Rearing and Emigration:** No impacts from exports on juvenile entrainment.
	Alternative 4	• **Juvenile Rearing and Emigration:** No impacts from exports on juvenile entrainment.

Impact	Alternative	Direction of Impacts
NATIVE MINNOWS		
Sacramento River		

Potential changes to Sacramento splittail, Sacramento hitch, and hardhead from seasonal operations	No Action	No measurable change from current operations.
		• **Hardhead:**
		  • *Adverse Component:* Rice Decomposition Smoothing.
		  • *Beneficial Components:* Ramping Rates and Water Temperature Management.
		  • *Adverse and/or Beneficial Components:* Spring Pulse Flows, Fall and Winter Refill and Redd Maintenance and Seasonal Operations.
		• **Sacramento Splittail:**
		  • *Adverse Component:* Rice Decomposition Smoothing.
		  • *Beneficial components:* Ramping Rates.
		  • *Adverse and/or Beneficial Components:* Fall and Winter Refill and Redd Maintenance and Seasonal Operations.
		• **Sacramento Hitch:**
		  • *Adverse Component:* Rice Decomposition Smoothing.
		  • *Beneficial Components:* Ramping Rates and Spring Pulse Flows.
		  • *Adverse and/or Beneficial Components:* Fall and Winter Refill and Redd Maintenance and Seasonal Operations.

	Alternative 1	• **Hardhead:** Negligible impacts from *flow*. Adverse impacts from *water temperatures*. • **Sacramento Splittail and Hitch:** Negligible impacts from *flow* and *water temperatures*.
	Alternative 2	• **Hardhead:** Negligible impacts from *flow*. Adverse impacts from *water temperatures* on spawning and non-spawning life stages. • **Sacramento Splittail and Hitch:** Negligible impacts from *flow* and *water temperatures*.
	Alternative 3	• **Hardhead:** Beneficial impacts from *flow* in the month of May for the lower river, possibly allowing for higher levels of downstream migration. Adverse and beneficial impacts from *water temperatures* on spawning. • **Sacramento Splittail and Hitch:** Beneficial impacts from *flow* in the month of May for the lower river, possibly allowing for higher levels of downstream migration. Negligible impacts from *water temperatures*.
	Alternative 4	• **Hardhead:** Negligible impacts from *flow*. Adverse impacts from *water temperatures* on spawning and negligible adverse and beneficial impacts on non-spawning. • **Sacramento Splittail and Hitch:** Negligible impacts from *flow*. Negligible impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
Clear Creek		
Potential changes to hardhead from seasonal operations	No Action	No change from current operations. Components of current operations by direction of impact are as follows: • **Adverse:** Seasonal Operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Water Temperature Management, Spawning and Rearing Habitat (targeted for salmonids). • **Adverse and/or Beneficial:** Pulse Flows
	Alternative 1	• Negligible impacts from *flow*. • Negligible impacts from *water temperatures*.
	Alternative 2	• Negligible impacts from *flow*. • Negligible impacts from *water temperatures*.
	Alternative 3	• Negligible impacts from *flow* on migrating and spawning adult hardhead. Adverse impacts in the fall on juvenile and non-spawning adults. • Negligible impacts from *water temperatures*.
	Alternative 4	• Negligible impacts from *flow* on migrating and spawning adult hardhead. Adverse impacts in the fall on juvenile and non-spawning adults. • Negligible impacts from *water temperatures*.
Lower American River		

Potential changes to Sacramento splittail and hardhead from seasonal operations	No Action	No change from current operations. Components of current operations by direction of impact are as follows:
		• **Hardhead**
		  • *Adverse:* Seasonal Operations.
		  • *Beneficial:* Ramping Rates, Minimum Instream Flows, Redd Dewatering Adjustments, Water Temperature Management, Spawning and Rearing Habitat Restoration (targeted for salmonids).
		  • *Adverse and/or Beneficial:* Spring Pulse Flows.
		• **Sacramento Splittail**
		  • *Adverse:* Seasonal Operations.
		  • *Beneficial:* Ramping Rates, Minimum Instream Flows, Redd Dewatering Adjustments, Spawning and Rearing Habitat Restoration (targeted for salmonids).

	Alternative 1	• **Hardhead:** Negligible impacts from *flow* on adult migration and spawning. Adverse impacts from *water temperature* on spawning. Negligible impacts from *water temperatures* on non-spawning. • **Sacramento Splittail:** Negligible impacts from *flow* on adult migration and spawning. Negligible impacts from *water temperatures* on spawning.

Impact	Alternative	Direction of Impacts
	Alternative 2	• **Hardhead:** Negligible impacts from *flow* on adult migration and spawning. Adverse impacts from *water temperatures* on spawning during some phases of Alternative 2. Negligible impacts from *water temperature* on non-spawning. • **Sacramento Splittail:** Negligible impacts from *flow* on adult migration and spawning. No anticipated impacts from *water temperatures* on spawning.
	Alternative 3	• **Hardhead:** Adverse impacts from *flow* on outmigration success, but beneficial impacts on spawning adults. Adverse and beneficial impacts from *water temperatures* on spawning and non-spawning, depending on the location. • **Sacramento Splittail:** Adverse impacts from *flow* on outmigration success, but beneficial impacts on spawning adults. Negligible impacts from *water temperatures* on spawning.
	Alternative 4	• **Hardhead:** Negligible impacts from *flow*. Beneficial and adverse impacts from *water temperatures* on spawning and non-spawning. • **Sacramento Splittail:** Negligible impacts from *flow*. No anticipated impacts from *water temperatures* on spawning.
Stanislaus River		
Potential changes to hardhead from seasonal operations	No Action	No change from current operations. Components of current operations by direction of impact are as follows: • **Adverse:** Fall Pulse Flows. • **Beneficial:** Seasonal Operations, Ramping Rates, Minimum Instream Flows, Winter Instability Flows, Spawning and Rearing Habitat Restoration (targeted for salmonids). • **Adverse and/or Beneficial:** Spring Pulse Flows.
	Alternative 1	Negligible impacts from *flow*. Adverse impacts from *water temperatures*.
	Alternative 2	Negligible impacts from *flow*. Adverse impacts from *water temperatures*.
	Alternative 3	Substantial beneficial impacts from *flow* on spawning, rearing, and outmigration. Negligible impacts from *water temperatures*.
	Alternative 4	Adverse impacts from *water temperatures* in dry water year types in the Stanislaus River below Goodwin. Negligible impacts from *water temperatures*.
San Joaquin River		
Potential changes to Sacramento splittail, Sacramento hitch, and hardhead from seasonal operations	No Action	The No Action Alternative reflects the 2020 Record of Decision evaluation of habitat restoration in concert with operations.
	Alternative 1	Negligible impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 2	Negligible impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 3	Substantial adverse impacts from *flow*. Negligible impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
	Alternative 4	Negligible impacts from *flow*. Negligible impacts from *water temperatures*.
Bay-Delta		
Potential changes to Sacramento splittail, Sacramento hitch, and hardhead from seasonal operations	No Action	No change from current operations. Components of current operations by direction of impact are as follows: • **Adverse:** Agricultural Barriers. • **Beneficial:** Spring Delta Outflow and Delta Smelt SFH. • **Adverse and/or Beneficial:** Seasonal Operations. • **Uncertain:** CCF Weed Management.
	Alternative 1	Negligible impacts and substantial adverse impacts from *flow* in below normal, dry, and critically dry water years on native minnows.
	Alternative 2	Adverse impacts from *flow* depending on month.
	Alternative 3	Beneficial impacts from *flow*.
	Alternative 4	Adverse impacts from *flow*.
Potential changes to entrainment of Sacramento splittail, Sacramento hitch, and hardhead	No Action	No measurable change from current operations. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	Adverse impacts from exports on entrainment.
	Alternative 2	Adverse impacts from exports on entrainment.
	Alternative 3	Beneficial impacts from exports on entrainment
	Alternative 4	Adverse and beneficial impacts from exports on entrainment
PACIFIC LAMPREY		
Trinity River		
Potential changes to Pacific lamprey from seasonal operations	No Action	• **Spawning and Egg Incubation:** Adverse impacts of *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse impacts of *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** Negligible impacts of *flow* and *water temperatures*.
	Alternative 1	• **Spawning and Egg Incubation:** Adverse impacts from *flow* and *water temperatures*. • **Ammocoete Rearing and Emigration:** Negligible adverse to beneficial impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** Beneficial to adverse impacts from *flow* and *water temperatures*
	Alternative 2	• **Spawning and Egg Incubation:** Adverse impacts from *flow* and *water temperatures*. • **Ammocoete Rearing and Emigration:** Adverse impacts from *flow* and *water temperatures*.

Impact	Alternative	Direction of Impacts
		• **Adult Upstream Migration and Holding:** Adverse impacts from *flow* and *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Adverse impacts from *flow* and *water temperatures*. • **Ammocoete Rearing and Emigration:** Negligible adverse to beneficial impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** Negligible adverse to beneficial impacts from *flow* and *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Negligible adverse impacts from *flow* and *water temperatures*. • **Ammocoete Rearing and Emigration:** Adverse impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** Adverse impacts from *flow* and *water temperatures*.
Sacramento River		
Potential changes to Pacific lamprey from seasonal operations	No Action	No measurable change from current operations. • **Adverse components:** Rice Decomposition Smoothing. • **Beneficial Components:** Ramping Rates, Spring Pulse Flows, Water Temperature Management. • **Adverse and/or Beneficial Components:** Seasonal Operations, Fall and Winter Refill and Redd Maintenance.
	Alternative 1	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negative impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Negligible impacts from *flow* and *water temperatures*.
Clear Creek		
Potential changes to Pacific lamprey from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Pulse Flows, Water Temperature Management, Spawning and Rearing Habitat (targeted to salmonids). • **Adverse:** Segregation Weir.

Impact	Alternative	Direction of Impacts
		• **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Adverse impacts from *flow*. Beneficial impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Beneficial impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Beneficial impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Beneficial impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
Lower American River		
Potential changes to Pacific lamprey from seasonal operations	No Action	No measurable change expected from current operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Spring Pulse Flows, Redd Dewatering Adjustments, Water Temperature Management, Spawning and Habitat Restoration (targeted for salmonids). • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow* and *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Adverse impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow* and *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Beneficial impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
Stanislaus River		
Potential changes to Pacific lamprey from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Spring Pulse Flows, Winter Instability Flows, Fall Pulse Flows, Spawning and Rearing Habitat Restoration (targeted for salmonids). • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
San Joaquin River		
Potential changes to Pacific lamprey from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	**Ammocoete Rearing and Emigration:** Beneficial to adverse impacts on rearing from *flow*. Beneficial impacts on emigration from *flow*. Negligible impacts on both life stages from *water temperatures*.
	Alternative 2	**Ammocoete Rearing and Emigration:** Beneficial impacts on rearing and negligible impacts on emigration from *flow*. Negligible impacts on both life stages from *water temperatures*.
	Alternative 3	**Ammocoete Rearing and Emigration:** Adverse impacts from *flow*. Negligible impacts on both life stages from *water temperatures*.
	Alternative 4	**Ammocoete Rearing and Emigration:** Negligible adverse to beneficial impacts from *flow*. Negligible impacts on both life stages from *water temperatures*.

Impact	Alternative	Direction of Impacts
Bay-Delta		
Potential changes to Pacific lamprey from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Spring Delta Outflow, and Delta Smelt SFH. • **Adverse:** Agricultural Barriers. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Ammocoete Rearing and Emigration:** Beneficial impacts from *flow* on juvenile emigration in critically dry years, Negligible impacts from *flow* on ammocoete rearing. • **Adult Migration:** Beneficial impacts from *flow* in critically dry water years
	Alternative 2	• **Ammocoete Rearing and Emigration:** Beneficial impacts from *flow* on juvenile emigration in critically dry years. Negligible impacts from *flow* on ammocoete rearing. • **Adult Migration:** Beneficial impacts from *flow* in the summer of critically dry years.
	Alternative 3	• **Ammocoete Rearing and Emigration:** Adverse and beneficial impacts from *flow* on juvenile emigration. Negligible impacts from *flow* on ammocoete rearing. • **Adult Migration:** Adverse impacts from *flow* in September of critically dry years.
	Alternative 4	• **Ammocoete Rearing and Emigration:** Beneficial impacts from *flow* on juvenile emigration in April of critically dry years. Negligible impacts from *flow* on ammocoete rearing. • **Adult Migration:** Beneficial impacts from *flow* in April of critically dry years.
Potential changes to entrainment of Pacific lamprey	No Action	No measurable change from current operations. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, and Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	Adverse impacts from exports on entrainment, increased loss predicted at CVP facility.
	Alternative 2	Beneficial to adverse impacts from exports on entrainment, loss increases and decreases at CVP facility
	Alternative 3	Beneficial impacts from exports on entrainment, decreased loss predicted at CVP facility.
	Alternative 4	Negligible impacts from *flow* on entrainment

Impact	Alternative	Direction of Impacts
WESTERN RIVER LAMPREY		
Sacramento River		
Potential changes to Western river lamprey from seasonal operations	No Action	No expected change from current operations. • **Beneficial Components:** Ramping Rates, Spring Pulse Flows, Water Temperature Management. • **Adverse and/or Beneficial Components:** Seasonal Operations, Fall and Winter Refill and Redd Maintenance.
	Alternative 1	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Adverse impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Beneficial impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Minor beneficial to minor adverse Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Beneficial impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
Lower American River		
Potential changes to Western river lamprey from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Spring Pulse Flows, Redd Dewatering Adjustments, Water Temperature Management, Spawning and Habitat Restoration (targeted for salmonids). • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Adverse to beneficial impacts from *flow*. Beneficial to adverse impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Adverse impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Adverse and beneficial impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Adverse and beneficial impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
Stanislaus River		
Potential changes to Western river lamprey from seasonal operations	No Action	No change from current operations. • **Beneficial:** Ramping Rates, Minimum Instream Flows, Spring Pulse Flows, Winter Instability Flows, Fall Pulse Flows, Spawning and Rearing Habitat Restoration (targeted for salmonids). • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow* and *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Beneficial impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*. • **Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	**Spawning and Egg Incubation:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
San Joaquin River		
Potential changes to Western River lamprey from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	**Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 2	**Ammocoete Rearing and Emigration:** Negligible adverse to beneficial impacts from *flow*. Negligible impacts on both life stages from *water temperatures*.
	Alternative 3	**Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.
	Alternative 4	**Ammocoete Rearing and Emigration:** Beneficial to adverse impacts from *flow*. Negligible impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
Bay-Delta		
Potential changes to Western river lamprey from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Spring Delta Outflow, and Delta Smelt SFH. • **Adverse:** Agricultural Barriers. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Ammocoete Rearing and Emigration:** Negligible adverse impacts from *flow* on ammocoete rearing. Beneficial impacts from *flow* on juvenile emigration in critically dry years. • **Adult Migration:** Negligible impacts from *flow*.
	Alternative 2	• **Ammocoete Rearing and Emigration:** Negligible impacts from *flow* on ammocoete rearing. Minor beneficial impacts from *flow* on juvenile emigration in critically dry years. • **Adult Migration:** Negligible impacts from *flow*.
	Alternative 3	• **Ammocoete Rearing and Emigration:** Negligible adverse impacts from *flow* on ammocoete rearing. Beneficial and adverse impacts from *flow* on juvenile emigration. • **Adult Migration:** Adverse impacts from *flow* in September of critically dry years.
	Alternative 4	• **Ammocoete Rearing and Emigration:** Negligible adverse impacts from *flow* on ammocoete rearing. Beneficial impacts from *flow* on juvenile emigration in April of critically dry water year types. • **Adult Migration:** Negligible impacts from *flow*.
Potential changes to entrainment of Western river lamprey	No Action	No measurable change from current operations. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** DCC Gates, Suisun March RRDS Fall Flood-up, Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	Adverse impacts from exports on entrainment predicted at CVP facility.
	Alternative 2	Beneficial impacts from exports on entrainment at the CVP facility in most water year types and negligible adverse impacts in wet years.
	Alternative 3	Beneficial impacts from exports on entrainment in most water years at the CVP facility.
	Alternative 4	Beneficial impacts from exports on entrainment in above normal and below normal years at the CVP facility. Adverse impacts from exports on entrainment in critically dry years.

Impact	Alternative	Direction of Impacts
STRIPED BASS		
Sacramento River		
Potential changes to striped bass from seasonal operations	No Action	No measurable change from current operations. • **Beneficial Component:** Water Temperature Management. • **Adverse and/or Beneficial Components:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Beneficial impacts from *flow* and *water temperatures*. • **Larval–Juvenile Rearing and Emigration:** Beneficial impacts from *flow* on rearing and emigration habitat. Negligible adverse impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Adverse impacts from *flow* on spawning habitat. Beneficial impacts from *water temperatures*. • **Larval–Juvenile Rearing and Emigration:** Adverse impacts from *flow* and negligible adverse impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Adverse impacts from *flow* and *water temperatures* on spawning habitat, spawning, and egg incubation. • **Larval–Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow*. Beneficial and adverse impacts from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Negligible adverse impacts from *flow* and negligible adverse and negligible beneficial impacts from *water temperatures* on spawning habitat, spawning, and egg incubation. • **Larval–Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and negligible beneficial impacts from *water temperatures* on rearing and emigration.
Lower American River		
Potential changes to striped bass from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Minimum Instream Flows, and Water Temperature Management, and Spawning and Habitat Restoration (targeted for salmonids). • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Adults:** Adverse impacts from flow. No anticipated impacts from *water temperatures*. • **Juvenile Rearing:** Minimal beneficial impacts from *flow* and *water temperatures*.
	Alternative 2	• **Adults:** Negligible adverse impacts from *flow* and no anticipated impacts from *water temperatures* on adults. • **Juvenile Rearing:** Negligible adverse impacts from *flow*. Adverse impacts from *water temperatures*.
	Alternative 3	• **Adults:** Beneficial and adverse impacts from *flow*. No anticipated impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
		• **Juvenile Rearing:** Beneficial and adverse impacts from *flow*. Beneficial (Hazel Avenue) and adverse (Watt Avenue) impacts from *water temperatures*.
	Alternative 4	• **Adults:** Negligible adverse impacts from *flow* and no anticipated impacts from *water temperatures*. • **Juvenile Rearing:** Negligible adverse impacts from *flow*. Beneficial and adverse impacts from *water temperatures*.
Stanislaus River		
Potential changes to striped bass from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Minimum Instream Flows, Spawning and Rearing Habitat Restoration (targeted for salmonids). • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Egg Incubation:** Beneficial impacts from *flow*. Adverse impacts from *water temperatures*. • **Larval–Juvenile Rearing and Emigration:** Beneficial impacts from *flow*. Beneficial and adverse impacts from *water temperatures*.
	Alternative 2	• **Spawning and Egg Incubation:** Adverse impacts from *flow*. Beneficial impacts from *water temperatures*. • **Larval–Juvenile Rearing and Emigration:** Beneficial impacts from *flow*. Adverse impacts from *water temperatures*.
	Alternative 3	• **Spawning and Egg Incubation:** Beneficial impacts from *flow*. Negligible adverse impacts from *water temperatures*. • **Larval–Juvenile Rearing and Emigration:** Beneficial and adverse impacts from *flow* on rearing and emigration. Adverse impacts (above confluence with San Joaquin) from *water temperatures*.
	Alternative 4	• **Spawning and Egg Incubation:** Adverse impacts from *flow* in April. Negligible impacts from *water temperatures*. • **Larval–Juvenile Rearing and Emigration:** Beneficial impacts from *flow*. Negligible adverse and negligible beneficial impacts from *water temperatures* on rearing.
San Joaquin River		
Potential changes to striped bass from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	**All Life Stages:** Beneficial and adverse impacts from *flow*. Negligible adverse impacts from *water temperatures*.
	Alternative 2	**All Life Stages:** Negligible adverse impacts from *flow* and beneficial impacts from flow in June through September of dry years. Negligible adverse impacts from *water temperatures*.
	Alternative 3	**All Life Stages:** Adverse impacts from *flow*. Negligible adverse impacts from *water temperatures*.
	Alternative 4	**All Life Stages:** Negligible adverse impacts from *flow* and beneficial impacts from flow in critically dry years. Negligible adverse impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
Bay-Delta		
Potential changes to striped bass from seasonal operations	No Action	No change from current operations. • **Adverse:** CCF Weed Management. • **Beneficial:** Agricultural Barriers. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	**All Life Stages:** Mixed adverse and beneficial impacts from *flows* at Delta export facilities and OMR. Negligible adverse impacts in most water years and beneficial impacts during critically dry years from Delta Outflow.
	Alternative 2	**All Life Stages:** Adverse and beneficial impacts from *flows*. Negligible adverse impacts in most water year types and beneficial impacts during critically dry years from Delta Outflow.
	Alternative 3	**All Life Stages:** Adverse and beneficial impacts from *flows*. Adverse impacts at Delta export facilities and OMR and beneficial impacts from Delta Outflow.
	Alternative 4	**All Life Stages:** Beneficial impacts from *flows* at Delta export facilities and OMR.
Potential changes to entrainment of striped bass	No Action	No measurable change from current operations. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, and Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility.
	Alternative 1	Adverse impacts from exports on entrainment at SWP Banks Pumping Plant export facility.
	Alternative 2	**Adult:** Beneficial and adverse impacts from exports on entrainment; beneficial impacts at CVP Jones Pumping Plant in most water year types on entrainment.
	Alternative 3	**Adult:** Beneficial impacts from exports on entrainment.
	Alternative 4	**Adult:** Beneficial and adverse impacts from exports on entrainment; adverse impacts at SWP Banks Pumping Plant and beneficial impacts at CVP Jones Pumping Plant on entrainment.
AMERICAN SHAD		
Sacramento River		
Potential changes to American Shad from seasonal operations	No Action	No measurable change from current operations. • **Adverse and/or Beneficial components:** Seasonal Operations.
	Alternative 1	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow*. Beneficial *water temperatures* impact.

Impact	Alternative	Direction of Impacts
	Alternative 2	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*.
	Alternative 3	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow*. Beneficial impact from *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow*. Beneficial impacts from *water temperatures*.
	Alternative 4	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and beneficial impacts from *water temperatures*.
Lower American River		
Potential changes to American shad from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Minimum Instream Flows. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow*. Beneficial impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible impacts from *flow*. Beneficial impacts from *water temperatures*.
	Alternative 2	• **Spawning and Larval Rearing:** Negligible impacts from *flow*. Beneficial and adverse impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse and beneficial impacts from *flow* and *water temperatures*.
	Alternative 3	• **Spawning and Larval Rearing:** Negligible adverse impact from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible impacts from *flow*. Beneficial impacts from *water temperatures*.
	Alternative 4	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow*. Adverse and beneficial impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow*. Adverse and beneficial impacts from *water temperatures*.
Stanislaus River		
Potential changes to American shad from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Minimum Instream Flows. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow*. Adverse impacts from *water temperatures*. • **Juvenile Rearing and Emigration:** Adverse impacts from *flow*. Beneficial impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
	Alternative 2	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*.
	Alternative 3	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*.
	Alternative 4	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*.
San Joaquin River		
Potential changes to American shad from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*.
	Alternative 2	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*.
	Alternative 3	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*.
	Alternative 4	• **Spawning and Larval Rearing:** Negligible adverse impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*.
Bay-Delta		
Potential changes to American shad from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Agricultural Barriers. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	Adverse impacts from *flow* on American shad abundance.
	Alternative 2	Negligible adverse impacts from *flow* on American shad abundance
	Alternative 3	Beneficial impacts from *flow* on American shad abundance.
	Alternative 4	Negligible adverse impacts from *flow* on American shad abundance.

Impact	Alternative	Direction of Impacts
Potential changes to entrainment of American shad	No Action	No measurable change from current conditions, continuation of current trends. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	Adverse impacts from exports on entrainment.
	Alternative 2	Adverse and beneficial impacts from exports on entrainment.
	Alternative 3	Beneficial impacts from exports on entrainment.
	Alternative 4	Adverse and beneficial impacts from exports on entrainment.
THREADFIN SHAD		
Sacramento River		
Potential changes to threadfin shad from seasonal operations	No Action	No measurable change from current operations. • **Adverse and/or Beneficial Components:** Seasonal Operations.
	Alternative 1	Negligible adverse impacts from *flow*. Beneficial and adverse impacts from *water temperatures* on spawning.
	Alternative 2	Negligible adverse impacts from *flow*. Negligible and adverse impacts from *water temperatures* on spawning.
	Alternative 3	Negligible impacts from *flow*. Beneficial and adverse impacts from *water temperatures* on spawning.
	Alternative 4	Negligible impacts from *flow*. Negligible impacts from *water temperatures* on spawning.
Lower American River		
Potential changes to threadfin shad from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Minimum Instream Flows. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	Negligible impacts from *flow*. Beneficial impacts from *water temperatures* on spawning.
	Alternative 2	Negligible adverse impacts from *flow*. Adverse and beneficial impacts from *water temperatures* on spawning.
	Alternative 3	Negligible impacts from *flow* and *water temperatures* on spawning.
	Alternative 4	Negligible impacts from *flow* and beneficial impacts from *water temperatures* on spawning.

Impact	Alternative	Direction of Impacts
Stanislaus River		
Potential changes to threadfin shad from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Spawning and Rearing Habitat Restoration (targeted for salmonids). • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	Negligible adverse impacts from *flow*. Adverse impacts from *water temperatures* on threadfin shad spawning.
	Alternative 2	Negligible impacts from *flow* and *water temperatures* on spawning.
	Alternative 3	Negligible impacts from *flow* and *water temperatures* on spawning.
	Alternative 4	Negligible impacts from *flow* and *water temperatures* on spawning.
San Joaquin River		
Potential changes to threadfin shad from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	Negligible impacts from *flow* and *water temperatures*.
	Alternative 2	Negligible impacts from *flow* and *water temperatures*.
	Alternative 3	Negligible impacts from *flow* and *water temperatures*.
	Alternative 4	Negligible impacts from *flow* and *water temperatures*.
Bay-Delta		
Potential changes to threadfin shad from seasonal operations	No Action	No measurable change from current operations. • **Adverse:** CCF Weed Management. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	Negligible impacts from *flow*.
	Alternative 2	Negligible impacts from *flow*.
	Alternative 3	Negligible impacts from *flow*.
	Alternative 4	Negligible impacts from *flow*.
Potential changes to entrainment of threadfin shad	No Action	No measurable change from current operations. • **Beneficial:** Seasonal and Real-Time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	Adverse and beneficial impacts from exports on entrainment.
	Alternative 2	Adverse and beneficial impacts from exports on entrainment.
	Alternative 3	Beneficial impacts from *flow* on entrainment.
	Alternative 4	Adverse and beneficial impacts from exports on entrainment.

Impact	Alternative	Direction of Impacts
BLACK BASSES		
Sacramento River		

Potential changes to largemouth, smallmouth, and spotted bass from seasonal operations	No Action	No measurable change from current operations.
		• **Largemouth and Spotted Bass**
		  • *Adverse Components:* Water Temperature Management.
		  • *Adverse and/or Beneficial Components:* Seasonal Operations.
		• **Smallmouth Bass**
		  • *Adverse and/or Beneficial Components:* Seasonal Operations.

	Alternative 1	• **Spawning Adults**
		  • *Largemouth, Smallmouth, and Spotted Bass:* Beneficial impacts from *flow*. No anticipated impacts from *water temperatures* on spawning.
		  • .
		• **Non-Spawning Adults**
		  • *Largemouth Bass:* Adverse impacts from *flow*. No anticipated impacts from *water temperatures*.
		  • *Smallmouth Bass:* Adverse impacts from *flow* and *water temperatures*.
		  • *Spotted Bass:* Adverse impacts from *flow*. Beneficial impacts from *water temperatures*.

	Alternative 2	• **Spawning Adults**
		  • *Largemouth, Smallmouth, and Spotted Bass:* Adverse impacts from *flow* on spawning habitat in June and July. No anticipated impacts from *water temperatures*.
		• **Non-Spawning Adults**
		  • *Largemouth and Spotted Bass:* Adverse impacts from *flow*. No anticipated impacts from *water temperatures*.
		  • *Smallmouth Bass:* Adverse impacts from *flow* and *water temperatures*.

	Alternative 3	• **Spawning Adults**
		  • *Largemouth and Spotted Bass:* Adverse impacts from *flow* on spawning habitat. No anticipated impacts from *water temperatures* on spawning.
		  • *Smallmouth Bass:* Adverse impacts from *flow* on spawning habitat. Adverse impacts from *water temperatures* on spawning.
		• **Non-Spawning Adults**
		  • *Largemouth Bass:* Adverse impacts from *flow*. No anticipated impacts from *water temperatures*.
		  • *Smallmouth Bass:* Adverse and beneficial impacts from *flow* and *water temperatures*.
		  • *Spotted Bass:* Adverse impacts from *flow*. No anticipated impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts

	Alternative 4	• **Spawning Adults**
		  • *Largemouth, Smallmouth, and Spotted Bass:* Negligible adverse impacts from *flow* on spawning habitat. No anticipated impacts from *water temperatures* on spawning.
		• **Non-Spawning Adults**
		  • *Largemouth Bass:* Adverse and beneficial impacts from *flow*. No anticipated impacts from *water temperatures*.
		  • *Smallmouth Bass:* Adverse and beneficial impacts from *flow*. Adverse and beneficial impacts from *water temperatures*.
		  • *Spotted Bass:* Adverse and beneficial impacts from *flow*. No Anticipated impacts from *water temperatures*.

Lower American River		

Potential changes to largemouth, smallmouth, and spotted bass from seasonal operations	No Action	No measurable change from current operations.
		• **Largemouth and spotted bass**
		  • *Beneficial:* Spawning and Habitat Restoration (targeted for salmonids).
		  • *Adverse and/or Beneficial:* Seasonal Operations.
		  • *Adverse:* Water Temperature Management.
		• **Smallmouth bass**
		  • *Beneficial:* Spawning and Habitat Restoration (targeted for salmonids).
		  • *Adverse and/or Beneficial:* Seasonal Operations.

	Alternative 1	• **Spawning Adults**
		  • *Largemouth Bass:* Beneficial and adverse impacts from *flow* on spawning habitat. Negligible beneficial impacts from *water temperatures* on spawning.
		  • *Smallmouth Bass:* Beneficial and adverse impacts from *flow* on spawning habitat. Beneficial and negligible adverse impacts from *water temperatures* on spawning.
		  • *Spotted Bass:* Beneficial and adverse impacts from *flow* on spawning habitat. Negligible adverse and beneficial impacts from *water temperatures* on spawning.
		• **Non-Spawning Adults**
		  • *Largemouth Bass:* Beneficial impacts from *flow*. No anticipated impacts from *water temperatures*.
		  • *Smallmouth Bass:* Beneficial impacts from *flow*. Adverse impacts from *water temperatures*.
		  • *Spotted Bass:* Beneficial impacts from *flow*. No anticipated impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts

	Alternative 2	• **Spawning Adults**
		  • *Largemouth Bass:* Negligible adverse impacts from *flow* on spawning habitat, except for beneficial impacts in April. Adverse impacts from *water temperatures*.
		  • *Spotted Bass:* Negligible adverse impacts from *flow* on spawning habitat, except for beneficial impacts in April. Beneficial and adverse impacts from *water temperatures*.
		  • *Smallmouth Bass:* Negligible adverse impacts from *flow* on spawning habitat, except for beneficial impacts in April. Negligible adverse impacts from *water temperatures*.
		• **Non-Spawning Adults**
		  • *Largemouth Bass*: Negligible adverse impacts from *flow*. No anticipated impacts from *water temperatures*.
		  • *Spotted Bass:* Negligible adverse impacts from *flow*. Negligible adverse impacts from *water temperatures*.
		  • *Smallmouth Bass:* Negligible impacts from *flow*. Adverse and beneficial impacts from *water temperatures* in the summer.

	Alternative 3	• **Spawning Adults**
		  • *Largemouth Bass:* Beneficial impacts from *flow* on spawning habitat in March through April and adverse impacts in June through July. Adverse and beneficial impacts from *water temperatures*.
		  • *Smallmouth Bass:* Beneficial impacts from *flow* on spawning habitat in March through April and adverse impacts in June through July. Adverse impacts from *water temperatures*.
		  • *Spotted Bass:* Beneficial impacts from *flow* on spawning habitat in March through April and adverse impacts in June through July. Adverse and beneficial impacts from *water temperatures*.
		• **Non-Spawning Adults**
		  • *Largemouth Bass:* Adverse impacts from *flow* below Nimbus Dam; beneficial impacts at H Street in June and July. No anticipated impacts from *water temperatures*.
		  • *Smallmouth and Spotted Bass:* Adverse impacts from *flow* below Nimbus Dam; beneficial impacts at H Street in June and July. Beneficial impacts from *water temperatures* at Watt Ave in the summer.

	Alternative 4	• **Spawning Adults**
		  • *Largemouth Bass:* Negligible adverse impacts from *flow* on spawning habitat. No anticipated impacts from *water temperatures*.
		  • *Smallmouth Bass:* Negligible adverse impacts from *flow* on spawning habitat. Adverse impacts from *water temperatures*.
		  • *Spotted Bass:* Negligible impacts from *flow* on spawning habitat. Beneficial impacts from *water temperatures*.
		• **Non-Spawning Adults**
		  • *Largemouth Bass:* Adverse and beneficial impacts from *flow*. No anticipated impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
		• *Smallmouth Bass:* Adverse and beneficial impacts from *flow*. Adverse and negligible beneficial impacts from *water temperatures* in the summer. • *Spotted Bass:* Adverse and beneficial impacts from *flow*. Beneficial impacts from *water temperatures*.
Stanislaus River		

Potential changes to largemouth, smallmouth, and spotted bass from seasonal operations	No Action	No measurable change from current operations.
		• **Largemouth and spotted bass**
		  • *Adverse:* Minimum Instream Flows.
		  • *Beneficial:* Spawning and Rearing Habitat Restoration (targeted for salmonids).
		  • *Adverse and/or Beneficial:* Seasonal Operations
		• **Smallmouth bass**
		  • *Beneficial:* Spawning and Rearing Habitat Restoration (targeted for salmonids).
		  • *Adverse and/or Beneficial:* Seasonal Operations

	Alternative 1	• **Spawning Adults**
		  • *Largemouth Bass:* Beneficial impacts from *flow* on spawning habitat. Negligible adverse impacts from *water temperatures* on spawning.
		  • *Spotted Bass:* Beneficial impacts from *flow* on spawning habitat. Adverse impacts from *water temperatures*.
		• **Non-Spawning Adults (largemouth, smallmouth, and spotted bass):** Beneficial impacts from *flow*. Negligible adverse impacts from *water temperatures*.

	Alternative 2	• **Spawning Adults (largemouth and spotted bass):** Negligible adverse impacts from *flow* on spawning habitat. Beneficial impacts from *water temperatures* on spawning. • **Non-Spawning Adults (largemouth, smallmouth, and spotted bass):** Beneficial impacts from *flow*. Negligible adverse impacts from *water temperatures*.

	Alternative 3	• **Spawning Adults**
		  • *Largemouth Bass:* Beneficial impacts from *flow* on spawning habitat. Adverse impacts from *water temperatures* on spawning.
		  • *Spotted Bass:* Beneficial impacts from *flow* on spawning habitat. Negligible adverse impacts from *water temperatures* on spawning.
		• **Non-Spawning Adults (largemouth, smallmouth, and spotted bass):** Beneficial impacts from *flow*. Negligible adverse impacts from *water temperatures*.

	Alternative 4	• **Spawning Adults (largemouth and spotted bass):** Negligible adverse impacts from *flow* on spawning habitat. Adverse impacts from *water temperatures* on spawning. • **Non-Spawning Adults (largemouth, smallmouth, and spotted bass):** Beneficial and adverse impacts from *flow*. Negligible adverse impacts from *water temperatures*.

Impact	Alternative	Direction of Impacts
San Joaquin River		
Potential changes to largemouth, smallmouth, and spotted bass from seasonal operations	No Action	No measurable change from current operations.
	Alternative 1	**Spawning Adults:** Beneficial impacts from *flow* on spawning habitat. Negligible adverse impacts from *water temperatures*.
	Alternative 2	**Spawning Adults:** Negligible adverse to beneficial impacts from *flow* during dry years on spawning habitat. Negligible adverse impacts from *water temperatures*.
	Alternative 3	**Spawning Adults:** Adverse and beneficial impacts from *flow* on spawning habitat. Negligible adverse impacts from *water temperatures*.
	Alternative 4	**Spawning Adults:** Negligible adverse to beneficial impacts from *flow* during critically dry years on spawning habitat. Negligible adverse impacts from *water temperatures*.
Bay-Delta		

Potential changes to largemouth, smallmouth, and spotted bass from seasonal operations	No Action	No measurable change from current operations.
		• **Largemouth Bass**
		  • *Adverse:* CCF Weed Management.
		  • *Beneficial:* Agricultural Barriers.
		  • *Adverse and/or Beneficial:* Seasonal Operations.
		• **Smallmouth and Spotted Bass**
		  • *Beneficial:* Agricultural Barriers.
		  • *Adverse and/or Beneficial:* Seasonal Operations.

	Alternative 1	**Non-Spawning Adults:** Beneficial impacts from *flow* on foraging habitat; adverse impact in November, and negligible adverse impacts in June and July.
	Alternative 2	**Non-Spawning Adults:** Adverse and beneficial impacts from *flow* on foraging habitat.
	Alternative 3	**Non-Spawning Adults:** Adverse impacts from *flow* on foraging habitat at one location, and beneficial impacts at two Delta locations.
	Alternative 4	**Non-Spawning Adults:** Beneficial impacts from *flow* on foraging habitat.
Potential changes to entrainment of largemouth, smallmouth, and spotted bass	No Action	No measurable change from current conditions, continuation of current trends. • **Beneficial:** Seasonal and Real-time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** DCC Gates, RRDS Fall Flood-up, Tracy Fish Collection Facility and John E Skinner Delta Fish Protective Facility.
	Alternative 1	**Juveniles:** Beneficial and adverse impacts from exports on entrainment. Adverse impacts on entrainment for all black bass species, except for a beneficial impact on spotted bass in November during dry years.

Impact	Alternative	Direction of Impacts
	Alternative 2	**Juveniles:** Beneficial impacts from exports on entrainment. Beneficial impacts on entrainment for black bass species, except for largemouth bass where adverse impacts would occur during below normal and critically dry years.
	Alternative 3	**Juveniles:** Adverse impacts from exports on entrainment. Beneficial impacts on entrainment for black bass species at CVP Jones and adverse impacts at SWP.
	Alternative 4	**Juveniles:** Beneficial impacts from exports on entrainment. Beneficial impacts on largemouth and smallmouth bass, and adverse and beneficial impacts on entrainment for spotted bass.
STARRY FLOUNDER		
Bay-Delta		
Potential changes to starry flounder from seasonal operations	No Action	No measurable change from current operations. • **Beneficial:** Spring Delta Outflow. • **Adverse and/or Beneficial Components:** Seasonal Operations.
	Alternative 1	Adverse impacts from *flow* on abundance, except in critically dry years.
	Alternative 2	Adverse impacts from *flow* on abundance, except in critically dry years.
	Alternative 3	Beneficial impacts from *flow* on abundance.
	Alternative 4	Adverse impacts from *flow* on abundance.
Potential changes to entrainment of starry flounder	No Action	No measurable change from current conditions, continuation of current trends. • **Beneficial:** Seasonal and Real-time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** RRDS Fall Flood-up, DCC Gates, and Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility.
	Alternative 1	Adverse impacts from exports on entrainment expected at both pumping plants, with SWP Banks pumping plant having a greater adverse impact.
	Alternative 2	Adverse impacts from exports on entrainment. Increased loss in all water year types except critically dry years at SWP Banks, minimal changes at CVP Jones across all water year types.
	Alternative 3	Beneficial impacts from exports on entrainment. Average monthly loss was beneficial at both facilities in wet years, negligible in dry years, and adverse in critically dry years.
	Alternative 4	Adverse impacts from exports on entrainment. Predicted average monthly loss was higher across all water year types at SWP Banks. At CVP Jones, loss was negligible across all water year types.

Impact	Alternative	Direction of Impacts
COASTAL PELAGIC SPECIES		
Bay-Delta		
Potential changes to Pacific herring and Northern anchovy from seasonal operations	No Action	No measurable change from current operations. • **Adverse and/or Beneficial:** Seasonal Operations.
	Alternative 1	• **Northern Anchovy:** Negligible adverse impacts on *flow* on habitat extent and indices of abundances. • **Pacific Herring:** Negligible impacts on *flow* on abundances.
	Alternative 2	• **Northern Anchovy:** Negligible adverse impacts on *flow* on habitat extent and indices of abundances. • **Pacific Herring:** Negligible adverse impacts on *flow* indices of abundances.
	Alternative 3	• **Northern Anchovy:** Negligible adverse impacts on flow on habitat extent and indices of abundances. • **Pacific Herring:** Negligible adverse impacts on *flow* on indices of abundances.
	Alternative 4	• **Northern Anchovy:** Negligible adverse impacts on flow habitat extent and indices of abundances. • **Pacific Herring:** Negligible adverse impacts on *flow* on indices of abundances.
Potential changes to entrainment of Pacific herring and Northern anchovy	No Action	No measurable change from current operations. • **Northern Anchovy:** Adverse –RRDS Fall Flood-Up. • **Pacific Herring:** Adverse –RRDS Fall Flood-Up. • **Beneficial:** Seasonal and Real-time Management of OMR Reverse Flow. • **Adverse and/or Beneficial:** Tracy Fish Collection Facility and John E. Skinner Delta Fish Protective Facility.
	Alternative 1	• **Northern Anchovy:** Negligible adverse impacts of flow on entrainment. • **Pacific Herring:** Potential adverse impacts from exports on entrainment in drier years.
	Alternative 2	• **Northern Anchovy:** Negligible impacts of flow on entrainment. • **Pacific Herring:** Negligible impacts from exports on entrainment.
	Alternative 3	• **Northern Anchovy:** Negligible impacts of flow on entrainment. • **Pacific Herring:** Potential beneficial impacts from exports on entrainment during drier years.
	Alternative 4	• **Northern Anchovy:** Negligible impacts of flow on entrainment. • **Pacific Herring:** Negligible impacts from exports on entrainment.

Impact	Alternative	Direction of Impacts
SOUTHERN OREGON/NORTHERN CALIFORNIA COAST COHO SALMON		
Trinity River		
Potential changes to coho salmon from seasonal operations	No Action	• **Spawning and Egg/Alevin Incubation:** No measurable changes in the availability or suitability of coho salmon spawning and egg/alevin incubation habitat. No adverse impacts of *flow* or *water temperatures* are expected. • **Juvenile Rearing and Emigration:** Substantial adverse changes in the availability or suitability of coho salmon rearing and emigration habitat are unlikely. No adverse impacts of *flow* or *water temperatures* are expected. • **Adult Upstream Migration and Holding:** Negligible adverse changes in the availability or suitability of coho salmon adult migration and holding habitat due to flow changes. No adverse impacts of *water temperatures* are expected.
	Alternative 1	• **Spawning and Egg/Alevin Incubation:** Spatially variable but negligible impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** No adverse impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** Spatially variable but negligible impacts from *flow* and *water temperatures*.
	Alternative 2	• **Spawning and Egg/Alevin Incubation:** Spatially variable negligible adverse to beneficial impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable negligible adverse to beneficial impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** Adverse to no impacts from *flow* and *water temperatures*.
	Alternative 3	• **Spawning and Egg/Alevin Incubation:** Spatially variable adverse to beneficial impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable adverse to beneficial impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** No impacts from *flow* or *water temperature*s
	Alternative 4	• **Spawning and Egg/Alevin Incubation:** Spatially variable but negligible adverse to beneficial impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable but negligible adverse to beneficial impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** Negligible adverse to no impacts from *flow* and *water temperatures*.

Impact	Alternative	Direction of Impacts
UPPER KLAMATH-TRINITY RIVER SPRING-RUN CHINOOK SALMON		
Trinity River		
Potential changes to spring-run Chinook salmon from seasonal operations	No Action	• **Spawning and Egg/Alevin Incubation:** No adverse changes in the availability or suitability of spawning and egg/alevin incubation habitat. • **Juvenile Rearing and Emigration:** No adverse changes in the availability or suitability of rearing and emigration habitat. • **Adult Upstream Migration and Holding:** No adverse changes in the availability or suitability of adult migration and holding habitat.
	Alternative 1	• **Spawning and Egg/Alevin Incubation:** Spatially variable but negligible impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable but negligible impacts from *flow* and *water temperatures*.
	Alternative 2	• **Spawning and Egg/Alevin Incubation:** Spatially variable negligible to minor beneficial impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable negligible adverse impacts from *flow* and *water temperatures*.
	Alternative 3	• **Spawning and Egg/Alevin Incubation:** Spatially variable negligible adverse to beneficial impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable negligible adverse impacts from *flow* and *water temperatures*.
	Alternative 4	• **Spawning and Egg/Alevin Incubation:** Spatially variable negligible adverse to beneficial impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable negligible adverse impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** No impacts from *flow* and *water temperatures*.
UPPER KLAMATH-TRINITY RIVER FALL-RUN CHINOOK SALMON		
Trinity River		
Potential changes to fall-run Chinook salmon from seasonal operations	No Action	• **Spawning and Egg/Alevin Incubation:** No adverse changes in the availability or suitability of spawning and egg/alevin incubation habitat. • **Juvenile Rearing and Emigration:** Negligible changes in the availability or suitability of rearing and emigration habitat. • **Adult Upstream Migration and Holding:** Negligible changes in the availability or suitability of adult migration and holding habitat.
	Alternative 1	• **Spawning and Egg/Alevin Incubation:** Spatially variable and negligible impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible impacts from *flow* and *water temperatures*.

Impact	Alternative	Direction of Impacts
	Alternative 2	• **Spawning and Egg/Alevin Incubation:** Spatially variable and negligible impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Negligible impacts from *flow* and *water temperatures*.
	Alternative 3	• **Spawning and Egg/Alevin Incubation:** Spatially variable and negligible impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable and negligible impacts from *flow* and *water temperatures*.
	Alternative 4	• **Spawning and Egg/Alevin Incubation:** Spatially variable and negligible impacts from *flow* and *water temperatures*. • **Juvenile Rearing and Emigration:** Spatially variable and negligible impacts from *flow* and *water temperatures*.
KLAMATH MOUNTAINS PROVINCE STEELHEAD DPS		
Trinity River		
Impact Statement	No Action	Negligible adverse impacts from *flow* and *water temperatures* for all life stages.
	Alternative 1	Negligible adverse impacts from *flow* and *water temperatures* for all life stages.
	Alternative 2	Negligible adverse impacts from *flow* and *water temperatures* for all life stages.
	Alternative 3	Negligible adverse impacts from *flow* and *water temperatures* for all life stages.
	Alternative 4	Negligible impacts from *flow* and *water temperatures* for all life stages except for adverse flow impacts to adult holding habitat in wet and above normal years.
NORTHERN DPS GREEN STURGEON		
Trinity River		
Potential changes to northern DPS green sturgeon from seasonal operations	No Action	No adverse impacts from *flow* and *water temperatures* in all life stages.
	Alternative 1	No adverse impacts from *flow* and *water temperatures* in all life stages.
	Alternative 2	Negligible adverse impacts from *flow* and *water temperatures* in all life stages.
	Alternative 3	• **Spawning and Egg Incubation:** Negligible adverse impacts from *flow* and *water temperatures*. • **Larval and Juvenile Rearing and Emigration:** Negligible adverse impacts from *flow* and *water temperatures*. • **Adult Upstream Migration and Holding:** Beneficial impacts from *flow* and *water temperatures* on migration and habitat.
	Alternative 4	• Negligible impacts from *flow* and *water temperatures* in all life stages.

Impact	Alternative	Direction of Impacts
EULACHON		
Trinity River		
Potential changes to Eulachon from seasonal operations	No Action	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 1	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 2	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 3	Negligible adverse impacts from *flow* and *water temperatures* on all life stages. Potential benefits on larval emigration from *flow* in January and February.
	Alternative 4	Negligible impacts from *flow* and *water temperatures* on all life stages.
COASTAL CUTTHROAT TROUT		
Trinity River		
Potential changes to coastal cutthroat trout from seasonal operations	No Action	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 1	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 2	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 3	Negligible adverse impacts from *flow* and *water temperatures* on all life stages. Potential benefits on larval emigration from *flow* in January and February
	Alternative 4	Negligible impacts from *flow* and *water temperatures* on all life stages.
BROWN TROUT		
Trinity River		
Potential changes to brown trout from seasonal operations	No Action	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 1	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 2	Negligible adverse impacts from *flow* and *water temperatures* on all life stages.
	Alternative 3	Negligible adverse impacts from *flow* and *water temperatures* on all life stages. Potential benefits on larval emigration from *flow* in January and February.
	Alternative 4	Negligible impacts from *flow* and *water temperatures* on all life stages.

Impact	Alternative	Direction of Impacts
TRINITY RESERVOIR SPECIES		
Trinity River		
Potential changes to Trinity reservoir species from seasonal operations	No Action	Negligible adverse impacts from *storage* and *water temperatures* on all species and life stages.
	Alternative 1	Negligible adverse impacts from *storage* and *water temperatures* on all species and life stages.
	Alternative 2	Negligible adverse impacts from *storage* and *water temperatures* on all species and life stages across all Alternative 2 phases
	Alternative 3	Negligible adverse impacts from *storage* and *water temperatures* on all species and life stages.
	Alternative 4	Negligible adverse impacts from *storage* and *water temperatures* on all species and life stages.
DELTA-MENDOTA CANAL / CALIFORNIA AQUEDUCT SPECIES		
Potential changes from seasonal operations	No Action	No adverse effect from water surface elevation and velocity changes.
	Alternative 1	No adverse effect from water surface elevation and velocity changes.
	Alternative 2	No adverse effect from water surface elevation and velocity changes.
	Alternative 3	No adverse effect from water surface elevation and velocity changes.
	Alternative 4	No adverse effect from water surface elevation and velocity changes.
CENTRAL VALLEY RESERVOIR SPECIES		
Shasta Reservoir		
Potential changes to Shasta reservoir species from seasonal operations	No Action	No adverse effect from reservoir storage on reproductive success and habitat availability.
	Alternative 1	No adverse effect from reservoir storage on reproductive success and habitat availability.
	Alternative 2	Beneficial effect from reservoir storage on reproductive success and habitat availability.
	Alternative 3	Beneficial effect from reservoir storage on reproductive success and habitat availability.
	Alternative 4	**Warmwater Species:** Beneficial effect from reservoir storage on reproductive success and habitat availability.
Whiskeytown Reservoir		
Potential changes to Whiskeytown reservoir species from seasonal operations	No Action	No adverse effect from reservoir storage on reproductive success or habitat availability.
	Alternative 1	No adverse effect from reservoir storage on reproductive success or habitat availability.
	Alternative 2	No adverse effect from reservoir storage on reproductive success or habitat availability.

Impact	Alternative	Direction of Impacts
	Alternative 3	No adverse effect from reservoir storage on reproductive success or habitat availability.
	Alternative 4	No adverse effect from reservoir storage on reproductive success or habitat availability.
Folsom Reservoir		
Potential changes to Folsom reservoir species from seasonal operations	No Action	No adverse effect from reservoir storage on reproductive success or habitat availability.
	Alternative 1	• **Warmwater Species:** Adverse effect from reservoir storage on reproductive success. • **Coldwater Species:** Beneficial effect from reservoir storage on habitat availability.
	Alternative 2	• **Warmwater Species:** No adverse effect from reservoir storage on reproductive success. • **Coldwater Species:** Adverse effect from reservoir storage on habitat availability, particularly in critically dry years.
	Alternative 3	• **Warmwater Species:** Beneficial effect from reservoir storage on reproductive success. • **Coldwater Species:** Both beneficial and adverse effect from reservoir storage on habitat availability.
	Alternative 4	• **Warmwater Species:** No adverse effect from reservoir storage on reproductive success. • **Coldwater species:** Both beneficial and adverse effect from reservoir storage on habitat availability.
New Melones Reservoir		
Potential changes to New Melones reservoir species from seasonal operations	No Action	No adverse effect from reservoir storage on reproductive success and habitat availability.
	Alternative 1	• **Warmwater Species:** Negligible adverse effect from reservoir storage on reproductive success. • **Coldwater Species:** Beneficial to adverse effect from reservoir storage on habitat availability.
	Alternative 2	• **Warmwater Species:** No adverse effect from reservoir storage on habitat availability. • **Coldwater Species:** No adverse effect in 3 phases from reservoir storage on habitat availability. Beneficial and adverse effects in Alternative 2 without TUCP Systemwide VA.
	Alternative 3	• **Warmwater Species:** Beneficial effect from reservoir storage on reproductive success. • **Coldwater Species:** No adverse effect from reservoir storage on habitat availability.
	Alternative 4	No adverse effect from reservoir storage on habitat availability.

Impact	Alternative	Direction of Impacts
San Luis Reservoir		
Potential changes to New Melones reservoir species from seasonal operations	No Action	No adverse effect from reservoir storage on reproductive success.
	Alternative 1	Beneficial effect from reservoir storage on habitat availability.
	Alternative 2	Beneficial or no effect from reservoir storage on habitat availability.
	Alternative 3	Mostly adverse effect with some beneficial effect from reservoir storage on habitat availability.
	Alternative 4	Beneficial or no effect from reservoir storage on habitat availability.
SOUTHERN RESIDENT KILLER WHALE DPS		
Pacific Ocean		
Impact Statement	No Action	No adverse impacts expected from modeled changes on adult Chinook salmon production in the Ocean.
	Alternative 1	Negligible beneficial impacts from modeled changes on adult Chinook salmon production in the Ocean.
	Alternative 2	Negligible adverse impacts from modeled changes on adult Chinook salmon production in the Ocean for Alternative 2 without TUCP without VAs, Alternative 2 with TUCP without VAs, and Alternative 2 without TUCP with Delta Vas. No adverse to beneficial impacts from modeled changes on adult Chinook salmon production in the ocean under Alternative 2 without TUCP all VAs.
	Alternative 3	Beneficial impacts and from modeled changes on adult Chinook salmon production in the Ocean.
	Alternative 4	Negligible beneficial impacts from modeled changes on adult Chinook salmon production in the Ocean.

O.9 Mitigation Measures

O.9.1 Alternative 1

O.9.1.1 Avoidance and Minimization Measures

Table O-283. Summary of Alternative 1 Avoidance and Minimization Measures

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
Ramping Rates	• Sacramento River (salmonids and sturgeon) • Clear Creek (salmonids) • American River (salmonids and sturgeon) • Stanislaus River (salmonids)	Changes in river elevation from reservoir releases can strand fishes. Ramping rates can decrease the risk of stranding of fishes; however, this benefit comes at the consequence of increasing water temperatures and dissolved oxygen levels.
Minimum Instream Flows	• Sacramento River (salmonids and sturgeon) • Clear Creek (salmonids) • American River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Certain hydrologic circumstances may cause short-term periods of high flows. Minimum instream flows are temporary reductions in reservoir releases to preserve water storage. Minimum instream flows store water in reservoirs and decrease flows resulting in increased and decreased water temperatures and dissolved oxygen levels, decreased and increased refuge habitat and spawning habitat dependent on geography, muted outmigration cues as a consequence of flattening the hydrograph, increased stranding and dewatering of eggs, decrease stranding and juvenile dewatering, and decreased food availability for smelt and the size of the Low Salinity Zone as a consequence of decreasing Delta inflow.
Water Temperature Management	• Sacramento River (salmonids and sturgeon) • Clear Creek (salmonids) • American River (salmonids and sturgeon)	Cooler water improves habitat.

O.9.1.2 Additional Mitigation

- **Mitigation Measure AQUA-1: Develop and Implement Program to Expand Adult Holding, Spawning, Egg Incubation, and Fry/Juvenile Rearing Habitat:** Reclamation will develop and implement a program to expand suitable adult holding, spawning, egg incubation, and fry/juvenile rearing habitat for Central Valley spring-run Chinook salmon, fall- /late fall-run Chinook salmon, and Central Valley steelhead elsewhere in the Northwestern California Diversity Group. The program will be designed to prevent hybridization and improve genetic integrity of spring-run Chinook salmon, and to improve spawning success, fry/juvenile survival, and production of all three species, thereby contributing to their recovery. Increases in Salmon and Steelhead production potential created by the program will equal or exceed the reduced production potential in Clear Creek that would result from cessation of the Clear Creek Restoration Program and reduced flows below Whiskeytown Dam.
- **Mitigation Measure AQUA-2: Delta Smelt Monitoring:** Reclamation will continue to monitor Delta smelt.
- **Mitigation Measure AQUA-3: Longfin Smelt Monitoring:** Reclamation will continue to monitor Longfin smelt.
- **Mitigation Measure AQUA-4: Fall-run Chinook Salmon Brood Year Assessment:** To assess the condition of fall-run Chinook salmon populations on CVP tributaries, a fall-run Chinook salmon brood year assessment for the previous year's cohort and the cohort of returning adults that hatched three years prior will be completed. The brood year assessment will be based on the best available science each year and teams may consider using indicators similar to the *Annual Winter-run Chinook Brood Year Assessment* that is part of Alternative 2. Information will be reviewed by technical teams coordinating specific divisions or watersheds and attached to the LTO Annual Report by Reclamation.

O.9.2 Alternative 2

O.9.2.1 Avoidance and Minimization Measures

Table O-284. Summary of Alternative 2 Avoidance and Minimization Measures

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
Ramping Rates = limit how quickly releases are reduced.	• Sacramento River (salmonids and sturgeon) • Clear Creek (salmonids) • American River (salmonids and sturgeon) • Stanislaus River (salmonids)	Changes in river elevation from reservoir releases can strand fishes. Ramping rates can decrease the risk of stranding of fishes; however, this benefit comes at the consequence of increasing water temperatures and dissolved oxygen levels.

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
Minimum Instream Flows	• Sacramento River (salmonids and sturgeon) • Clear Creek (salmonids) • American River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Certain hydrologic circumstances may cause short-term periods of high flows. Minimum instream flows are the lowest level of flow allowed and are prescribed to protect beneficial uses. Minimum instream flows store water in reservoirs and decrease flows resulting in increased and decreased water temperatures and dissolved oxygen levels, decreased and increased refuge habitat and spawning habitat dependent on geography, muted outmigration cues as a consequence of flattening the hydrograph, increased stranding and dewatering of eggs, decrease stranding and juvenile dewatering, and decreased food availability for smelt and the size of the Low Salinity Zone as a consequence of decreasing Delta inflow.
Pulse Flows = releases of water from reservoirs can result in pulses of flows in rivers.	• Sacramento River (salmonids and sturgeon) • Clear Creek (salmonids) • Bay-Delta (salmonids, sturgeon, and smelt) • American River (salmonids and sturgeon)	Pulse flows are spatiotemporally coordinated releases to benefit migration of fish. Pulse flows can decrease and increase water temperature stressors, increase outmigration travel Rate and decrease outmigration travel time, decrease entrainment risk, increase redd dewatering potential, and increase food availability for smelt and size of the Low Salinity Zone as a consequence of increased Delta inflow.
Fall and Winter Baseflows for Shasta Reservoir Refill and Redd Maintenance	• Sacramento River (salmonids and sturgeon)	Required storage management or flood control releases must be balanced with supporting refill capabilities for Shasta Reservoir to build the coldwater pool for the following year. Fall and Winter Baseflows build and conserve storage to balance pool management with salmonid redd dewatering risk and baseflows are set annually to balance that risk in the coming fall and winter with the following year. Fall and Winter Baseflows may increase or decrease the risk of redd dewatering, water temperatures, refuge habitat and food availability, and outmigration cues.
Adult Migration & Holding Water Temperature Objectives	• Sacramento River (salmonids and sturgeon)	Under a circumstance where low flows combined with warm air temperatures and/or an intentional warmwater power bypass cause water temperatures to rise to concerning levels prior to the final Temperature Management Plan, Reclamation will begin temperature management as early as March 1st through May to target water temperatures of 58°F daily average at CCR.

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
SRS Contractors: Delaying or Shifting Spring Diversions, Shifting Timing of Delivery of Transfer Water, Rice Decomposition Smoothing	• Sacramento River (salmonids)	Reclamation may request that the Sacramento River Settlement Contractors (SRSC) delay diversions in the spring to increase the likelihood that Shasta Reservoir elevations reach the upper gates on the Temperature Control Device. Reclamation may request that the SRSC shift timing of delivery of transfer water to increase the amount of water in Shasta Reservoir through the water temperature management season. Final decision making is done by the SRSC; therefore, these two actions are not analyzed. Rice decomposition smoothing involves coordination of diversions to lower peak rice decomposition demand. Early reductions balance the potential for winter-run Chinook salmon dewatering with water demands. The measure may impact stranding, redd dewatering, refuge habitat, and outmigration in the fall.
Flow and Non-Flow Measures from the Voluntary Agreements	• Sacramento River (salmonids) • Bay-Delta (salmonids and smelt)	Flow and non-flow measures may increase flows in the spring prior to the water temperature management season, at the cost of depleting the coldwater pool, to advance inflows to the Delta. These measures may also decrease flows in the summer. Increased flows from increased spring releases may lower water temperatures for adult salmonids while decreased flows in the summer may increase water temperatures. Juvenile and yearling salmonids may benefit from increased spring flows which would decrease travel time and increase migration rates. Flow and non-flow measures from the VAs may also increase Delta inflow increasing food availability for smelt and the size / location of the Low Salinity Zone.
Wilkins Slough Minimum Flow Criteria Relief	• Sacramento River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Minimum flows at Wilkins Slough are targeted in certain driest of year water years, particularly summer flows. Minimum flows are met under considerations for storage, fisheries, and water deliveries. Minimum flow criteria relief may decrease water temperatures in the following year if Shasta Reservoir coldwater pool is conserved; however, this benefit comes at the consequence of increasing water temperatures by decreasing spring and summer releases. Minimum flow criteria may also decrease Delta inflow decreasing food availability for smelt.

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
Rebalancing between other CVP Reservoirs	• Sacramento River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Rebalancing between reservoirs can be used to conserve Shasta Reservoir storage and operate the TCD to temperature targets. Rebalancing allows for temperature management during critical salmonid spawning and egg incubation; however, this benefit comes at the consequence of increased water temperatures when spring and summer flows are reduced. Rebalancing may also decrease Delta inflow decreasing food availability for smelt and size / location of the Low Salinity Zone.
Limitation on CVP Allocations for EOS storage	• Sacramento River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Water supply reductions may occur in dry water years, with the goal of conserving storage and meeting minimal water temperature objectives. The goal of reductions is to increase end of September storage for Shasta Reservoir. Limitation on allocations may increase end of September storage which may provide increased coldwater pool in the following year; however, this benefit may come at the cost of increased water temperatures when summer flows are reduced. Limitations may also decrease Delta inflow decreasing food availability for smelt.
Modifications to Water Transfers	• Sacramento River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Modifications to water transfers involve shifting the timing of delivery of transfer water during the typical irrigation season. Water transfer modifications may help improve water temperature management, protect winter-run Chinook salmon redds from dewatering, and fall-run Chinook salmon from stranding; however, this benefit of increased Sacramento River flows may come at the cost of decreased storage in Shasta Reservoir and subsequent decreased coldwater pool volume the following year. Water transfer modifications may also increase Delta inflow increasing food availability for smelt.
Situation-Specific Adjustments to Delta Water Quality Standards	• Sacramento River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Sacramento River flows may decrease in dry years as one approach to conserving storage in Shasta Reservoir. Relaxation of Delta outflow and salinity requirements historically occur in the winter, spring, and summer. The measure may increase or decrease the water temperature related impacts. Water temperatures may increase with lower flows in the Sacramento River during the summer and may decrease the following year by increasing the volume of water in storage. The measure

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
		may impact outmigration and refuge habitat with lower flows in the Sacramento River during the winter.
Limitations in SRS Contractors Water Available Under Contract	• Sacramento River (salmonids and sturgeon)	Sacramento River flows may decrease in the spring, summer, and fall of dry years as one approach to conserving storage in Shasta Reservoir. The measure may increase or decrease the water temperature related impacts. Water temperatures may increase with lower flows in the Sacramento River during the spring, summer, and fall; and may decrease temperatures the following year by increasing the volume of water in storage. The measure may impact entrainment through routing and migration timing, outmigration cues, and refuge habitat.
Refuge Coordination for Instream Flow, Lake Levels, and Refuge Needs	• Sacramento River (salmonids and sturgeon)	Shasta Reservoir releases to refuges in the summer and fall may decrease during the driest of years to increase Shasta Reservoir storage. The measure may increase or decrease water temperatures. Decreasing Sacramento River flows may warm in-river temperatures; however, conserving Shasta Reservoir storage may reduce water temperatures in the following year. The measure may also impact outmigration by decreasing Sacramento River flows.
Egg Incubation and Emergence Water Temperature Objectives	• Sacramento River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Water temperature management would target 53.5°F through operation of the Temperature Control Device on Shasta Dam, selectively withdrawing and blending water from different elevations within Shasta Reservoir. Water temperatures are typically targeted from May 15 – October 30; however, start and end dates may be adjusted through coordination with the SRG and SHOT based on the winter-run Chinook salmon spawning and emergence. The measure may increase or decrease water temperatures. Water temperature management may reduce stress May 15 - October 30; however, reducing Shasta Reservoir storage may increase water temperatures in the following year. The measure may impact outmigration and refuge habitat in the fall and winter by decreasing Sacramento River flows.
Annual Winter-Run Chinook	• Sacramento River	Based on the outcome of the broodyear assessment prepared by the Winter-run JPE sub-team, Reclamation, NMFS, USFWS and CDFW will convene appropriate

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
Salmon Brood Year Assessment		technical staff to make recommendations if it is necessary to increase the production of winter-run Chinook salmon associated with the Integrated-Recovery Supplementation Program or take other actions to protect production of winter-run Chinook salmon at the LSNFH. USFWS, through coordination with the SHOT, will implement measures as appropriate. The outcome of the broodyear assessment may also be considered in implementing actions within the drought toolkit. Reclamation believes this is a USFWS action.
Drought Operations Priority Framework	• Sacramento River (salmonids and sturgeon) • Bay-Delta (salmonids, sturgeon, and smelt)	Reclamation will develop a Drought Emergency Plan that establishes system priorities and seeks to provide Winter-run Chinook salmon spawning water temperatures. The measure may increase or decrease the water temperatures by decreasing Sacramento River flows into the Delta; however, increasing Shasta Reservoir storage may provide for more suitable water temperatures in the following year. The measure may also impact outmigration by decreasing Sacramento River flows into the Delta.
Clear Creek Water Temperature Management	• Clear Creek (salmonids and sturgeon)	Reclamation will target Whiskeytown Dam releases to not exceed the mean daily temperatures at Igo gage: • 61°F from June 1 through August 15. • 60°F from August 16 through September 15. • 56°F from September 16 through November 15. In dry, critical, or transfer curtailment years, Reclamation may not be able to meet these water temperatures and will operate Whiskeytown Dam as close to these water temperatures as practical. Water temperature management in Clear Creek will subsequently impact salmonids in the Sacramento River below the confluence. Cooler water temperatures below Whiskeytown may provide a benefit to salmonids.
Redd Dewatering Protective Adjustment	• American River (salmonids)	Adjusts the minimum release requirements to account for hydrology and potential dewatering impacts to fall-run Chinook salmon redds in January and February and steelhead redds in February through May based on the minimum release requirements. The measure may decrease stranding and dewatering by softening changes in the minimum release requirements.

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
Folsom Reservoir Flow and Temperature Management	• American River (salmonids)	Reclamation will implement the Automated Temperature Selection Procedure, which was developed in consultation with representatives of state and federal agencies and prioritizes water temperatures during the summer to support steelhead rearing over water temperatures in the fall to support fall-run Chinook salmon spawning. The measure is expected to be beneficial by targeting lower water temperatures in the summer, at the consequence of potentially increasing water temperatures in the fall due to release of cold water.
Winter Instability Flows	• Stanislaus River (salmonids)	Reclamation releases additional flow in February to simulate natural variability in the winter hydrograph and to enhance access to varied rearing habitats. Reclamation, through the Stanislaus Watershed Team, schedules the winter instability flow volume. Whenever possible, the pulse is scheduled to coincide with a natural storm event, which may naturally cue outmigration. In some years, natural rain events may provide sufficient natural variability in the hydrograph and an additional pulse may be determined to be necessary. The measure may decrease water temperatures and provide more rearing habitat in the winter at the consequence of reducing reservoir storage and potentially increasing water temperatures in subsequent months.
DCC Gates Closures	• Bay-Delta (salmonids, sturgeon and smelt)	Reclamation closes the Delta Cross Channel during the late fall, winter, and spring to reduce straying of fall-run Chinook salmon, protect outmigrating salmonids from entering the interior Delta, facilitate the State Water Board D-1641 Rio Vista flow objectives for fish passage, and reduce potential scouring and flooding that might occur in the channels on the downstream side of the gates when Sacramento River flows exceed 20,000 cfs on a sustained basis. The measure may decrease entrainment risk by potentially aquatic species from being diverted into the interior Delta.

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
Barker Slough Pumping Plant	• Bay-Delta (smelt)	DWR proposes to operate the BSPP to protect larval Delta Smelt from March 1 to June 30 of dry and critical water years. If the water year type changes after March 1 to below normal, above normal, or wet, this action will be no longer in effect. If the water year type changes after March 1 to dry or critical, DWR proposes to operate according to this measure. The measure may benefit Delta smelt and longfin smelt through reduced entrainment risk.
Tracy Fish Collection Facility and Skinner Delta Fish Protective Facility	• Bay-Delta (salmonids, sturgeon and smelt)	Reclamation will operate the Tracy Fish Collection Facility to screen fish from Jones Pumping Plant. The primary channel is a behavioral barrier with effectiveness that depends on the pumping Jones Pumping Plant. The secondary channel is a positive fish barrier. When south Delta hydraulic conditions allow and conditions are within the original design criteria for the Tracy Fish Collection Facility, the secondary channel is operated to achieve water approach velocities for striped bass of approximately 1 to 2.5 feet per second from June 1 through October 31 and for salmon of approximately 3 feet per second from November 1 through May 31. The measure may decrease entrainment risk by potentially preventing aquatic species from being entrained at the export facility.
Old and Middle River Flow Management Start	• Bay-Delta (salmonids, sturgeon and smelt)	Reclamation will reduce exports to achieve a 7-day average OMR value no more negative than -5,000 cfs for seven consecutive days when the genetically verified 7-day rolling sum of winter-run early season migration and spring-run Chinook salmon loss, calculated daily, exceeds the following annually calculated thresholds. The measure may decrease entrainment risk by potentially preventing aquatic species from being entrained at the export facility.
Old and Middle River Management Real Time Operation	• Bay-Delta (salmonids, sturgeon and smelt)	Reclamation and DWR will manage diversion rates from the South of Delta modified based on abiotic and biotic factors for several listed species. The measure may decrease entrainment risk by potentially preventing aquatic species from being entrained at the export facility.

Avoidance and Minimization Measure	Geography and Listed Species Impacted	Impact
Summer and Fall Delta Outflow and Habitat	• Bay-Delta (salmonids, sturgeon and smelt)	Reclamation and DWR will maintain a 30-day average X2 ≤ 80 km for September through November in Wet and Above Normal years. The measure may decrease entrainment risk by increasing flows in the Delta and, thus, benefiting the migratory transport to the estuary and potentially preventing entrainment at the export facility. The measure may also benefit outmigration and food availability by increasing flow through the Delta.
Spring Delta Outflow	• Bay-Delta (salmonids, sturgeon and smelt)	Reclamation and DWR will take actions intended to supplement Delta outflow per the terms of the VAs approved by the SWRCB and executed agreements by Voluntary Agreement (VA) Parties. The measure may decrease entrainment risk by increasing migratory transport to the estuary, potentially preventing entrainment at the export facility. The measure may also benefit outmigration cues and food availability by increased flow through the Delta.
Delta Smelt Supplementation	• Bay-Delta (smelt)	Reclamation and DWR, through the Culture and Supplementation of Smelt Steering Committee, will continue to collaborate with USFWS and CDFW on the development of a program to conduct supplementation of the wild Delta smelt population with propagated fish consistent with USFWS' Supplementation Strategy (USFWS 2020), which document is currently being updated by CDFW and USFWS. The measure is expected to be generally beneficial to the Delta smelt population due to the increased releases into the Delta.

O.9.2.2 Additional Mitigation

Same as Alternative 1.

O.9.3 Alternative 3

O.9.3.1 Avoidance and Minimization Measures

Water Temperature Clear Creek

Relevant to fish and aquatic resources because it will improve the water temperature conditions for relevant fisheries. Reclamation will manage Whiskeytown Dam releases to not exceed mean daily water temperatures of 60°F at the Igo gauge from June 1 through September 15 and 56°F from September 15 through November 15.

Minimum Instream Flows (Minimum Release Requirements) American River

Relevant to fish and aquatic resources because it will improve coldwater pool and habitat conditions for steelhead and fall-run Chinook salmon. Reclamation would incorporate the following Folsom Reservoir storage requirements:

- **EOS:** 300 TAF (230 TAF in a second consecutive dry or critical water year type).
- **EOD:** 300 TAF. Reclamation would prioritize minimum flows under the MRR, then storage, then additional Delta outflow in the winter and spring, then water deliveries.

Old and Middle River Reverse Flows

Relevant to fish and aquatic resources because this measure may decrease entrainment risk by potentially preventing aquatic species from being entrained at the export facility.

- From the earlier of January 1 or the onset of OMR management, until the earlier of June 30 or the offramp of OMR Management, OMR flows shall not exceed -5,000 cfs on a 14-day running average. These requirements do not apply when San Joaquin River flows at Vernalis are greater than 20,000 cfs. In addition, when the SVI has been classified as a critically dry year for a second (or more) consecutive year, OMR flows shall not exceed -2,500 cfs on a 14-day running average.
- From April 1 to May 31, Reclamation and DWR shall operate to achieve a 2:1 ratio of San Joaquin River inflow at Vernalis to combined CVP/SWP exports in all water year types.

Winter and Spring Delta Outflow

Relevant to fish and aquatic resources because it is intended to reduce the adverse impacts of CVP/SWP operations on listed species, by increasing abundance and productivity of longfin smelt, increasing survival of winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead (as a result of increased flows that increased survival in the Sacramento River and increase survival through the Delta), increasing recruitment of Delta smelt, and increasing survival and abundance of green sturgeon. Reclamation and DWR shall operate to meet the Delta Outflow criteria in Appendix E, Table E.6 1 for the months of July to November. For the months of December through June, on a monthly basis, Reclamation and DWR shall operate to meet Delta Outflow that is the lesser of 65 percent of unimpaired Delta inflow or the Delta Outflow criteria in Table E.6 1.

- Reclamation and DWR shall bypass 55% of unimpaired inflow to Shasta, Folsom, and Oroville reservoirs and 40% of unimpaired inflow to New Melones Reservoir. If the storage requirements and monthly Delta Outflow criteria in Alternative 3 are met, then releases from Shasta, Folsom, and Oroville reservoirs that month may be reduced to 45% of unimpaired inflows from December through May. Reclamation and DWR may release stored water to meet Delta outflow criteria in May through November.
- Reclamation and DWR would prioritize meeting the storage requirements described in Alternative 3 before making additional reservoir releases beyond what is required to meet D-1641 and human health and safety.

Delta Smelt Summer and Fall Habitat

Relevant to fish and aquatic resources because it may decrease entrainment risk by increasing flows in the Delta and, thus, benefitting the migratory transport to the estuary and potentially preventing entrainment at the export facility. The measure may also benefit outmigration and food availability by increasing flow through the Delta. Releases from upstream reservoirs are constrained to a Delta outflow of 7,100 cfs in November of wet and above normal years. Fall salinity may vary based on the ability of export reductions to achieve Fall X2 subject to public health and safety.

Drought

Relevant to fish and aquatic resources because it improves temperature conditions, migration, and increase hatchery production for relevant fisheries. Alternative 3 prohibits the use of a temporary urgency change petition. Alternative 3 does not include construction nor operation of the Drought Barrier in West False River.

Other actions may be considered and analyzed as necessary. Reclamation and DWR, through Governance, may update the toolkit.

O.9.3.2 Additional Mitigation

Same as Alternative 1.

O.9.4 Alternative 4

O.9.4.1 Avoidance and Minimization Measures

Water Temperature Management

Relevant to fish and aquatic resources because it will improve the temperature conditions for relevant fisheries.

Reclamation will target Whiskeytown Dam releases to not exceed the mean daily water temperatures at Igo gauge:

- 61°F from June 1 through August 15.
- 60°F from August 16 through September 15.
- 56°F from September 15 through November 15.

Water temperature management on Clear Creek is implemented through changes in guard gate configurations and flow manipulations. In dry, critical, or import curtailment years, Reclamation may not be able to meet these water temperatures, and will operate Whiskeytown Dam as close to these temperatures as practicable.

By June 15, Reclamation, through Governance, will annually prepare a TMP for the summer through fall. By May 15, Reclamation will provide a draft TMP to solicit input through tributary groups, in this case the American River Group. The priority for use of the lowest water temperature control shutters at Folsom Dam, within operational constraints, would be to achieve the water temperature requirement for steelhead, and may also be used to provide cold water for fall-run Chinook salmon spawning. During plan implementation, if the water temperature is exceeded for three consecutive days, or is exceeded by more than 3°F for a single day, Reclamation, will notify NMFS through Governance, and outline steps to realign lower American River water temperatures with the TMP. Reclamation will implement the ATSP described in the 2023 Updates and Refinements to the Lower American River 2017 Flow Management Standard Technical Memorandum.

Minimum Instream Flows (Minimum Release Requirement) American River

Relevant to fish and aquatic resources because it will improve coldwater pool and habitat conditions for steelhead and fall-run Chinook salmon. Reclamation would adopt the minimum flow schedule outlined in the 2023 Updates and Refinements to the Lower American River 2017 Flow Management Standard Technical Memorandum. The 2023 Updates and Refinements to the Lower American River 2017 Flow Management Standard Technical Memorandum includes MRR ranges from 500 to 2000 cfs based on time of year and annual hydrology. The flow schedule is intended to improve coldwater pool and habitat conditions for steelhead and fall-run Chinook salmon.

Old and Middle River Flow Management

Relevant to fish and aquatic resources because it may decrease entrainment risk by potentially preventing aquatic species from being entrained at the export facility.

Reclamation and DWR will reduce exports to achieve OMR no more negative than -5,000 cfs when one or more of the following conditions have occurred:

- **"First Flush":** In addition to the reduction in exports described in the No Action Alternative, Reclamation and DWR may initiate the "first flush" if, through Governance, monitoring indicates a high risk of migration and dispersal of smelt into areas at high risk of future entrainment. "First Flush" may be offramped to OMR no more negative than -5,000 cfs if the San Joaquin River at Vernalis is flowing at 10,000 cfs or more.
- **Delta Smelt Salvage:** After December 1 if the Enhanced Delta Smelt Monitoring Program observes Delta smelt in the Lower San Joaquin River and Southern Delta region or if any salvage of Delta smelt occurs. Reclamation and DWR, through Governance, may cease OMR restrictions related to this trigger or adjust the trigger requirements if hatchery release and monitoring data indicate that Delta smelt catch within the south Delta represent <5% of the overall catch.

- **Adult Longfin Salvage:** After December 1 if monitoring data indicates that longfin smelt catch within the south Delta represent ≥5% of the overall catch or if any salvage of longfin smelt occurs. Reclamation and DWR, through Governance, may cease OMR restrictions related to this trigger if monitoring data (e.g., Enhanced Delta Smelt Monitoring Program, Bay Study, Fall Midwater Trawl) indicate that longfin smelt catch within the south Delta represent <5% of the overall catch.

- **Juvenile Salmonid Salvage:** After December 1, Reclamation and DWR, through Governance, may incorporate additional or different predictive models as necessary to improve the onset of OMR management season for salmonid species if any of the following occurs: Gaeta et al.'s (2023) machine learning model predicts one week in advance the presence of winter-run length-at-date juvenile Chinook salmon across all 30 submodels, or salvage of genetically confirmed juvenile winter-run or spring-run Chinook salmon, or annual cumulative loss total reaches 60 or above for wild Central Valley steelhead.

- **Real-time Adjustments:** In addition to "First Flush", additional restrictions use real-time monitoring to identify an increased risk of entrainment. Reclamation and DWR will manage to a more positive OMR than -5,000 cfs under the following conditions:

- **Adult Delta Smelt Turbidity Protection:** Reclamation and DWR would manage exports to OMR no more negative than -2,000 cfs when daily average turbidity at both Holland Cut, and Old River at Bacon Island are at or above 12 FNU. Reclamation and DWR will maintain OMR at no more negative than -2,000 cfs for one week, and then no more negative than -3,500 cfs until measured daily average turbidity at both sensors are less than 12 FNU, or as revised through Governance.

    - Adult Delta smelt protection will off-ramp when three-day average water temperature at Jersey Point reaches 59ºF. This off ramp will be based on data from the San Joaquin River at Jersey Point averaged over three days.

- **Delta Smelt Larvae and Juveniles Protection:** Larval and juvenile Delta smelt management period will initiate when detected within the entrainment zone based on real-time sampling, or adult Delta smelt protection has off-ramped based on water temperature, whichever comes first. The presence of Delta smelt larvae and juveniles can also be identified through a detection of spent adult females in survey or salvage. Reclamation and DWR will restrict exports to allow OMR no more negative than -3,500 cfs when Secchi depth average measurement is equal or less than one meter.

- **Longfin Smelt Larvae and Juveniles Protection:** Recent studies indicated that regulations limiting Delta export for salmonids and Delta smelt since 2008-2009 have been protective for populations of longfin smelt.

- **Winter-run Annual Cumulative Loss Thresholds:** Reclamation and DWR will manage OMR to remain below the total annual loss thresholds for genetically-verified winter-run Chinook salmon at the Tracy and Skinner fish facilities:
    - Natural Winter-run Chinook salmon: Salvage Loss <0.5% of JPE (same as the No Action Alternative)
    - Hatchery Winter-run Chinook salmon: Salvage Loss <0.5% of JPE

During the brood year, if at any time cumulative loss of natural or hatchery winter-run Chinook salmon exceed the total annual loss threshold, DWR and Reclamation would restrict south Delta exports to maintain an OMR value of no more negative than -3,500 cfs for 14 days. Reclamation and DWR, through Governance, will also develop, implement, and update weekly an OMR schedule for the rest of the OMR management season to avoid further exceeding the annual loss thresholds using entrainment prediction tools and documented in an assessment.

- **Winter-run Chinook Salmon High Salvage Avoidance:** Reclamation and DWR will reduce exports to achieve OMR of no more negative than -3,500 cfs for at least seven days when Gaeta et al.'s (2023) machine learning model predicts one week in advance the high presence of winter-run length-at-date juvenile Chinook salmon across all 30 submodels. High presence is defined as seven-day moving average of more than 4.29 winter-run Chinook salmon expanded salvage at the salvage facilities. This action can only occur in the months of February, March, and April. OMR would continue to be managed to be no more negative than -3,500 cfs for longer than seven days until Gaeta et al.'s (2023) model no longer predicts high presence across all submodels.
- **Spring-Run Chinook Salmon Surrogate Thresholds:** Reclamation and DWR will reduce exports to achieve OMR no more negative than -3,500 cfs for seven days the first instance cumulative salvage loss of a release group equals or exceeds 0.5% of the releases group at Delta entry. Reclamation and DWR, through Governance, will develop the locations and times of in-river surrogate releases to best represent natural juvenile spring-run Chinook salmon migration into the Sacramento River and Delta. The percentage of the release group at Delta entry will be determined by survival from the release site to the Delta, similar to the development of the winter-run Chinook salmon JPE.
- **Storm Flex:** Reclamation and DWR may operate to an OMR no more negative than -6,250 cfs to capture peak flows during storm-related events when no backstop conditions are triggered and following conditions are met:
    - The Delta is in excess conditions as defined in 2018 amendment to the COA, and
    - QWEST is greater than 0.

DWR and Reclamation, through Governance, will use estimates of the real-time distribution of winter-run Chinook salmon, Particle Track Model, and prediction tool output to assess potential winter-run Chinook salmon entrainment risk differences using OMR inputs of -5000, and -6250 cfs. If the assessment indicates that additional entrainment protections are unlikely to be triggered, Reclamation and DWR may operate to OMR no more negative than -6,250 cfs and

will update the assessment no less than weekly. If conditions indicate a backstop condition is likely to trigger, Reclamation and DWR will resume OMR no more negative than -5,000 cfs. If a backstop condition is triggered, Reclamation and DWR will cease storm-flex and implement the backstop.

O.9.4.2 Additional Mitigation

Same as Alternative 1.

O.10 Cumulative Impacts

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Impacts Technical Appendix*, may have cumulative effects on fish and aquatic resources, to the extent that they could affect potential changes in habitat, water storage capacity, water conveyance infrastructure, water recycling capacity, and the reoperation of existing water supply infrastructure.

Past and present actions contribute to the existing condition of the affected environment in the project area while reasonably foreseeable actions are those that are likely to occur in the future that are not speculative. Past, present, and reasonably foreseeable projects include actions to develop water storage capacity, water conveyance infrastructure, water recycling capacity, the reoperation of existing water supply infrastructure, including surface water reservoirs and conveyance infrastructure, and habitat restoration actions. The projects identified in Appendix Y that have the most potential to contribute to cumulative impact on fish and aquatics resources are:

- B.F. Sisk Dam Raise and Reservoir Expansion Project (except for Alternative 2)
- Sites Reservoir Project (except for Alternative 2)
- Delta Conveyance Project (except for Alternative 2)
- Fremont Weir Adult Fish Passage Modification Project
- Knights Landing Outfall Gates (KLOG) Fish Barrier Project
- Wallace Weir Fish Rescue Facility Project
- California Eco Restore
- Lower Yolo Restoration Project
- Yolo Bypass Habitat Restoration Project
- Suisun Habitat Management, Preservation and Restoration Plan
- Construction of Folsom Lake Temperature Control Device
- Red Bluff Diversion Dam Passage Improvement Project
- Upper Sacramento River Anadromous Fish Habitat Restoration Project

- Lower American River Anadromous Fish Habitat Restoration Project
- Franks Tract Project
- San Joaquin River Restoration Program
- San Francisco Bay Delta Action Plan
- Bay-Delta Water Quality Control Plan Update
- Feather River Fish Hatchery
- Coleman National Fish Hatchery
- Nimbus Fish Hatchery
- Mokelumne Fish Hatchery
- Merced River Fish Facility
- Bradmoor Island
- Lookout Slough
- Prospect Island
- Chipps Island
- Cache Slough Area Restoration
- Prospect Island Tidal Habitat Restoration Project

O.10.1 Sacramento River

Major factors contributing to the cumulative impacts on aquatic biological resources in the Sacramento River have included major instream water storage dams, hydropower development and operations, hatchery management from the Coleman National Fish Hatchery and the Feather River Fish Hatchery, water withdrawals for irrigation and other uses, agricultural and urban development, channelization and levee construction, mining activities, recreational use and development, sport and commercial fisheries, introduction of nonnative fish species, and other management actions, water uses, and land uses (Appendix Y, *Cumulative Methodology*). These actions have resulted in highly altered flow regimes, loss and disconnection of floodplains from the river channel, altered sediment transport, reduced aquatic habitat complexity, loss of riparian and off-channel aquatic habitat, loss of upstream habitat, elevated water temperature, degraded water quality, habitat fragmentation by physical barriers, and other adverse effects on aquatic biological resources. Several ecosystem improvement projects and actions, including the Central Valley Project Improvement Act (CVPIA), the CALFED Bay-Delta Program, California EcoRestore, CDFW Ecosystem Restoration Program, and various other conservation, management, and restoration programs (Appendix Y), have been initiated to offset the adverse effects of previous and ongoing activities.

In addition to the ongoing activities, several probable future projects and programs may affect listed fishes and other aquatic biological resources in the Sacramento River. New projects and programs recently implemented or likely to be implemented in the near future are listed in Appendix Y, *Cumulative Methodology*. Some of these projects and programs may negatively impact status fishes and critical habitat in the Sacramento River, but others are likely to be beneficial. While some projects and actions have had beneficial effects, the net short-term effect of many new and ongoing programs, projects, and restoration efforts remains uncertain. In the long term, however, the net effects are expected to include substantial improvements in river habitat conditions and conservation or recovery of special-status fish populations. Despite ongoing and potential future projects that could benefit native Sacramento River fishes and their habitat, it is apparent that the effects of past and present actions have resulted in a cumulative adverse effect on winter-run Chinook salmon, spring-run Chinook salmon, steelhead, green sturgeon, and designated critical habitat in the Sacramento River for each of these species.

O.10.1.1 Anadromous Salmonids

No Action Alternative

The following components of the No Action Alternative have been identified as potentially resulting in impacts (adverse or beneficial) on one or more of the anadromous salmonid species or runs, green and white sturgeon, and other focal fish species. These components include seasonal operations, rice decomposition smoothing, ramping rates, fall and winter refill and redd maintenance, spring pulse flows, Shasta Reservoir coldwater pool management, winter-run Chinook salmon supplementation and spawning and rearing habitat restoration.

The No Action Alternative is expected to result in infrequent exposure of eggs and alevins to injuriously warm water temperatures during summer and fall, dropping water levels that lead to redd dewatering during the fall, or inadequate pulse flows for rearing and emigrating juveniles in the spring. These changes are expected to contribute to cumulative effects on winter-run Chinook salmon and spring-run Chinook salmon.

Steelhead, fall-run Chinook salmon, and late fall–run Chinook salmon are less affected by the management tradeoffs between storing and releasing water between under the No Action Alternative because they spawn when river water temperatures are cooler. Under the No Action Alternative there is a mixture of potential negative and positive changes.

Alternatives 1–4

Components that may impact anadromous salmonids under the action alternatives include seasonal operations (Alternative 1, 2, 3, 4), rice decomposition smoothing (Alternative 1, 2, 3, 4), ramping rates (Alternative 1, 2, 3), fall and winter baseflows for Shasta refill and redd maintenance (Alternative 2), CVP spring pulse flows (Alternative 2), winter and spring pulses and Delta outflow (Alternative 3), Sacramento River Settlement Contractors voluntary agreements spring pulse flows (Alternative 2), Shasta Reservoir water temperature management (Alternative 1, 3, 4), Shasta Reservoir water temperature and storage management (Alternative 2), minimum instream flows (Alternative 1, 2), fall and winter instream flows (Alternative 4), and adult migration and holding temperature objectives (Alternative 2).

Past, present and reasonably foreseeable projects include components that affect the timing and magnitude of flow releases and seasonal water temperatures and components that improve habitat of rearing and migrating salmonids in the Sacramento River. Flow and water temperature effects of completed projects are generally accounted for in the operational modeling of the No Action Alternative and Alternatives 1-4. Of the water supply and water quality projects that have not been completed, the most likely to have cumulative effects related to the flow and water temperature effects of Alternative 2 is the Bay-Delta Water Quality Control Plan Update.

The Bay-Delta Water Quality Control Plan Update has the potential to modify Sacramento River flow. Potential effects from the Bay-Delta Water Quality Control Plan Update would result in increased flows in spring and decreased flows in summer, with subsequent decreased water temperature in spring and increased water temperature in summer. This increase in flows may have a cumulative beneficial flow effect on salmonids, particularly juveniles, which are migrating downstream towards the Delta. The decrease in summer flows may contribute to a potential negative effect.

Relative to the No Action Alternative, Alternative 2 and Alternative 4 would have impacts on Sacramento River anadromous salmonids. For winter-run Chinook salmon, these would include beneficial water temperature effects for incubating eggs and alevins (Alternative 2) and minor adverse to beneficial rearing habitat flow effects. For spring-run Chinook salmon, water temperature effects and flow effects of Alternative 2 and Alternative 4 would be similar to the No Action Alternative for incubating eggs and alevins and on rearing habitat. For steelhead, these would include beneficial water temperature effects (Alternative 2) and adverse to beneficial water temperature effects (Alternative 4) for incubating eggs and adverse to beneficial rearing habitat flow effects (Alternative 2 and 4). For fall-run Chinook salmon, these benefits would include adverse to beneficial impacts from flow (Alternative 2 and 4) on egg incubation and rearing habitat and adverse to beneficial impacts from water temperature (Alternative 2) on rearing habitat. For late fall-run Chinook salmon, these would include beneficial water temperature effects (Alternative 2) for incubating eggs and adverse to beneficial (Alternative 2) and adverse (Alternative 4) rearing habitat flow effects. Relative to the No Action Alternative, Alternative 1 and Alternative 3 would also result in impacts on Sacramento River anadromous salmonids. For winter-run Chinook salmon, these impacts would include adverse (Alternative 1) and adverse or beneficial (Alternative 3) water temperature effects for incubating eggs and alevins. For spring-run Chinook salmon, Alternative 1 and Alternative 3 would have similar effects as for winter-run Chinook salmon. For steelhead, these impacts would include adverse water temperature effects (Alternative 1) and adverse to beneficial water temperature effects (Alternative 3) for incubating eggs and adverse to beneficial rearing habitat flow effects (Alternative 1 and 3). For fall-run Chinook salmon, these impacts would include adverse impacts from water temperature on rearing (Alternative 1 and 3), beneficial impacts (Alternative 1) and adverse to beneficial impacts (Alternative 3) from flow on egg incubation, and adverse impacts from flow (Alternative 1 and 3) on rearing habitat. For late fall-run Chinook salmon, these would include adverse (Alternative 1) and beneficial water temperature effects (Alternative 3) for incubating eggs and adverse (Alternative 1) and adverse to beneficial (Alternative 3) flow effects on rearing habitat.

Given the mixture of potential adverse and beneficial effects from the components in the action alternatives, and related actions in the Bay-Delta Water Quality Control Plan Update, there is some uncertainty in how these alternatives would ultimately affect salmonids. Under Alternative 1 may contribute to water temperature cumulative impacts for all salmonids while Alternatives 2, 3 and 4, population level effects are not expected to contribute to cumulative impacts.

O.10.1.2 Green and White Sturgeon

Most of the proposed components primarily target anadromous salmonids, but many of them potentially affect sturgeon as well. Green sturgeon is generally more likely to be affected than white sturgeon because its spawning, holding and rearing habitats are further upstream than those of white sturgeon and most of the proposed components primarily target conditions in the upper Sacramento River.

The projects to be considered cumulatively include components that affect the timing and magnitude of flow releases and seasonal water temperatures, and components that improve habitat of rearing and migrating green sturgeon in the Sacramento River. Flow and water temperature effects of completed projects are generally accounted for in the operational modeling of the No Action Alternative and the action alternatives of the water supply and water quality projects that have not been completed, those most likely to have cumulative effects related to the flow and water temperature is the Bay-Delta Water Quality Control Plan Update. The Bay-Delta Water Quality Control Plan Update has the potential to modify Sacramento River flow. Potential effects from the Bay-Delta Water Quality Control Plan Update would result in increased flows in spring and decreased flows in summer, with subsequent decreased water temperature in spring and increased water temperature in summer. This increase in spring flows may add to the potential beneficial effect on green sturgeon, but the decrease in summer flows may contribute to a potential negative effect.

No Action Alternative

Given the mixture of potential adverse and beneficial changes from the components in the No Action Alternative and related actions in the Bay-Delta Water Quality Control Plan Update, there is some uncertainty in how these alternatives would ultimately affect green sturgeon. However, the No Action Alternative is not expected to result in population level effects to green sturgeon and, hence, will not contribute to cumulative effects on green sturgeon.

Alternative 1–4

Given the mixture of potential adverse and beneficial effects from the components in the action alternatives, and related actions in the Bay-Delta Water Quality Control Plan Update, there is some uncertainty in how the action alternatives would ultimately affect green sturgeon. Relative to the No Action Alternative, Alternative 1 is not expected to have population level effects on green sturgeon, except minor negative flow effects to all life stages. Alternative 2 compared to the No Action Alternative is not expected to result in population level effects on green sturgeon. Alternative 3 is not expected to result in population level effects on green sturgeon, except for adverse flow effects on larval and juvenile rearing and emigration. Alternative 4 is not expected to result in impacts on green sturgeon, except for minor beneficial flow effects on larval and juvenile rearing and adult upstream migration. Therefore, Alternatives 1-4 are not expected to contribute to cumulative impacts on green sturgeon.

None of the proposed components under the action alternatives are expected to result in a population level effect on white sturgeon. For all white sturgeon life stages and behaviors, the alternatives are not expected to include flow or water temperature changes that would cause adverse impacts. Thus, the action alternatives are not expected to contribute to cumulative impacts on white sturgeon.

O.10.1.3 Other Focal Fish Species

This section addresses cumulative effects on the remaining Sacramento River populations of the focal fish species not included as anadromous salmonids or green sturgeon and white sturgeon: Sacramento splittail, hardhead, Sacramento hitch, Pacific lamprey, western river lamprey, striped bass, American shad, threadfin shad, largemouth bass, smallmouth bass, and spotted bass. None of these is a federally listed species.

The proposed components under both the No Action Alternative and Alternatives 1-4 primarily target anadromous salmonids and none of them are expected to result in population level effects to other focal species listed above. Therefore, the No Action Alternative and Alternatives 1-4 are not expected to result in cumulative impacts on these species.

O.10.2 Clear Creek

Major factors contributing to cumulative impacts on aquatic biological resources in Clear Creek have included hydropower development and operations, water withdrawals for irrigation and other uses, agriculture, timber harvest, roadbuilding, mining activities, channelization and levee construction, recreational use and development, sport and commercial fisheries, introduction of nonnative fish species, and other management actions, water uses, and land uses (Appendix Y, *Cumulative Methodology*). These actions have resulted in highly altered flow regimes, loss and disconnection of floodplains from the river channel, altered sediment transport, reduced aquatic habitat complexity, loss of riparian and off-channel aquatic habitat, elevated water temperature, degraded water quality, habitat fragmentation by physical barriers, and other adverse effects on aquatic biological resources. Several ecosystem improvement projects and actions, including the Central Valley Project Improvement Act (CVPIA), the CALFED Bay-Delta Program, the Clear Creek Restoration Program, the CDFW Ecosystem Restoration Program and various other conservation, management, and restoration programs (Appendix Y), have been initiated to offset the adverse effects of previous and ongoing activities.

In addition to the ongoing activities, several probable future projects and programs may affect listed fishes and other aquatic biological resources in Clear Creek. New projects and programs recently implemented or likely to be implemented in the near future are listed in Appendix Y, *Cumulative Methodology*. Some of these projects and programs may negatively impact special-status fishes and critical habitat in Clear Creek, but others are likely to be beneficial. While some projects and actions have had beneficial effects, the net short-term effect of many new and ongoing programs, projects, and restoration efforts remains uncertain. In the long term, however, the net effects are expected to include substantial improvements in river habitat conditions and conservation or recovery of special-status fish populations. Despite ongoing and potential future projects that could benefit native fishes and their habitat in Clear Creek, it is apparent that the effects of past and present actions have resulted in a cumulative adverse effect on Central Valley spring-run Chinook salmon, Central Valley steelhead, and their designated critical habitat in

Clear Creek. Also, these actions have resulted in a cumulative adverse effect on fall-run Chinook salmon in Clear Creek.

O.10.2.1 Anadromous Salmonids

This section addresses cumulative impacts on the Clear Creek populations of the following anadromous salmonids: spring-run Chinook salmon, Central Valley steelhead, fall-run Chinook salmon and late fall–run Chinook salmon.

No Action Alternative

The following components of the No Action Alternative have been identified as potentially resulting in impacts (adverse or beneficial) on anadromous salmonids in Clear Creek. These components include seasonal operations, ramping rates, segregation weir, minimum instream flows, pulse flows and water temperature management.

The expected benefits and impacts typically involve a tradeoff between the benefit of release water from storage in one year and with the impact of conserving insufficient storage for the next year. For instance, seasonal operations must balance providing cool water for releases to Clear Creek for water temperature control objectives and maintaining water temperature objects in the Sacramento River by supplying water to Keswick Reservoir with the impact of providing storage for the following year. This applies to seasonal operations of all the alternatives including the No Action Alternative. The costs and benefits of using water in one year versus using it in the following year are difficult to gage and likely vary from year to year, so the net effect on the salmonid populations is uncertain. For some of the other components, such as use of a segregation weir, there would be expected benefits primarily to spring-run Chinook salmon. However, weir location and timing would be planned to minimize effects to other salmonids utilizing Clear Creek.

The No Action Alternative is expected to have effects on anadromous salmonids in Clear Creek. However, these effects are not expected to result in adverse population-level impacts. Thus, the No Action Alternative is not expected to contribute to cumulative impacts on Clear Creek anadromous salmonids.

Alternatives 1–4

The following components of the action alternatives have been identified as potentially resulting in impacts (adverse or beneficial) on anadromous salmonids in Clear Creek. These components include seasonal operations (Alternatives 1-4), ramping rates (Alternatives 1-4), segregation weir (Alternatives 1-4), minimum instream flows (Alternatives 1-4), pulse flows (Alternatives 2-4), and water temperature management (Alternatives 1-4).

Relative to the No Action Alternative, Alternative 1 is expected to result in effects on Clear Creek anadromous salmonids. For spring-run Chinook salmon, this effect would include negative and beneficial flow effects with potential negative flow effects on spawning and fry/juvenile rearing habitat and negligible water temperature effects except potential beneficial effects on spawning and egg incubation. For steelhead, this effect would include negative and beneficial flow effects with potential adverse flow effects on spawning habitat and negative flow effects on fry and juvenile rearing habitat and negligible water temperature effects except possible beneficial effects on spawning and incubation.

Relative to the No Action Alternative, Alternatives 2, 3, and 4 would have an effect on Clear Creek anadromous salmonids. For both steelhead and spring-run Chinook salmon, this would include adverse and beneficial flow and temperature effects. Alternatives 2, 3, and 4 would not include population level flow or temperature effects on steelhead or spring-run Chinook salmon.

Given the mixture of potential adverse and beneficial effects from the action alternative, there is some uncertainty in how these alternatives would ultimately affect anadromous salmonids. However, in consideration that Alternatives 2, 3, and 4 are unlikely to cause population level effects, these alternatives are not expected to contribute to cumulative effects on anadromous salmonids in Clear Creek. Alternative 1, on the other hand, may result in adverse flow effects on steelhead spawning and fry/juvenile rearing habitat. Thus, Alternative 1 may contribute to cumulative effects on steelhead in Clear Creek.

O.10.2.2 Other Focal Fish Species

This section addresses cumulative effects on the remaining Clear Creek populations of the non-salmonid focal fish species: hardhead and Pacific lamprey. Neither of these is a federally listed species.

The proposed components under both the No Action Alternative and Alternatives 1-4 primarily target anadromous salmonids and none of them are expected to result in population level effects to other focal species listed above. Therefore, the No Action Alternative and Alternatives 1-4 are not expected to result in cumulative impacts on these species.

O.10.3 Lower American River

The lower American River is a highly altered watershed. Historical and management actions led to the reduction of available habitat, degraded habitat conditions, and substantial reduction of fish populations in the river. While these impacts were acknowledged as a trade-off for other water management priorities in the past, measures have been taken to improve conditions in the lower American River (Appendix Y). As such, there are numerous ongoing actions in and around the American River that may result in cumulative effects. Many of these actions are working to restore or improve conditions, so the resultant effect may not necessarily be an adverse cumulative impact. For example, the proposed Folsom Reservoir Temperature Control Device would withdraw water from the warm upper reaches of the lake while preserving the coldwater pool at the bottom of the reservoir to protect downstream aquatic species. Implementation of these measures to would help to improve habitat conditions in the American River, particularly in dry years, by maintaining minimum instream flows and suitable water temperatures.

The following components of the action alternatives have been identified as potentially resulting in impacts (adverse or beneficial) on anadromous salmonids in the lower American River. These components include seasonal operations (Alternatives 1-4), ramping rates (Alternatives 1-4), minimum instream flows (Alternatives 1-4), spring pulse flows (Alternatives 2-4), winter and spring pulses (Alternatives 3), Delta outflow (Alternatives 3), redd dewatering adjustments and water temperature management (Alternatives 1, 2 and 4).

O.10.3.1 Anadromous Salmonids

This section addresses cumulative impacts on the lower American River populations of steelhead and fall-run Chinook salmon.

No Action Alternative

The following components of the No Action Alternative have been identified as potentially resulting in impacts (adverse or beneficial) on anadromous salmonids in the lower American River. These components include seasonal operations, ramping rates, minimum instream flows, spring pulse flows, redd dewatering adjustments and water temperature management.

The expected benefits and impacts typically involve a tradeoff between the benefit of release water from storage in one year and with the impact of conserving insufficient storage for the next year. For instance, seasonal operations, limited coldwater pool, and limited storage require balancing releases and shutter operations to maximize the ability to maintain suitable water temperatures for steelhead rearing and fall-run Chinook salmon spawning. This applies to seasonal operations of all the alternatives including the No Action Alternative. The costs and benefits of using water in one year versus using it in the following year are difficult to gage and likely vary from year to year, so the net effect on the salmonid populations is uncertain. For some of the other components, such as implementation of redd dewatering adjustments, there would be expected benefits because projective adjustments may limit potential steelhead redd dewatering.

The No Action Alternative is expected to have effects on anadromous salmonids in the lower American River. The No Action Alternative may result in adverse flow effects on steelhead fry/juvenile rearing habitat. Thus, the No Action Alternative may contribute to cumulative effects on steelhead in the lower American River.

Alternatives 1–4

Relative to the No Action Alternative, Alternative 2 would have an effect on lower American River anadromous salmonids. For both steelhead and fall-run Chinook salmon, this would include adverse and beneficial flow and temperature effects. Alternatives 3 and 4 would have adverse and beneficial flow and temperature effects, including beneficial flow effects on redd dewatering in drier water year types. For fall-run Chinook salmon, Alternative 3 and 4 would include adverse and beneficial flow effects; however, none of these effects is expected to result in population level effects. Relative to the No Action Alternative, Alternative 1 would also have an effect on lower American River anadromous salmonids. For steelhead, this would include adverse and beneficial flow effects, including flow effects on redd dewatering potential in drier water year types. For fall-run Chinook salmon, this effect would include adverse and beneficial flow effects, including adverse flow effects on spawning and egg incubation and beneficial flow effects on juvenile rearing and emigration.

All the action alternatives are expected to result in cumulative effects on steelhead in the lower American River. Alternative 1 may contribute to cumulative effects on fall-run Chinook salmon.

O.10.3.2 Other Focal Fish Species

This section addresses cumulative effects on the remaining American River populations of the focal fish species not included as anadromous salmonids: white sturgeon, Sacramento splittail,

hardhead, Pacific lamprey, western river lamprey, striped bass, American shad, threadfin shad, largemouth bass, smallmouth bass, and spotted bass.

The proposed components under both the No Action Alternative and Alternatives 1-4 primarily target anadromous salmonids and none of them are expected to result in population level effects to other focal species listed above. Therefore, the No Action Alternative and Alternatives 1-4 are not expected to result in cumulative impacts on these species.

O.10.4 Bay-Delta

Major factors contributing to cumulative impacts on aquatic biological resources in the Bay-Delta have included water withdrawals for irrigation and other uses, agriculture, channelization and levee construction, recreational use and development, sport and commercial fisheries, introduction of nonnative fish species, and other management actions. Of the water supply and water quality projects not included in the modeling, those most likely to have cumulative effects are the Bay-Delta Water Quality Control Plan Update, and Cache Slough Area Restoration. The Bay-Delta Water Quality Control Plan has the potential to increase Delta inflow and outflow during spring months, reduce Delta inflow and outflow during fall months, and reduce south Delta exports. The Cache Slough Area Restoration project has the potential to improve habitat and lower food web conditions by increasing floodplain, riparian, marsh, and open water habitat. The construction and operation of Agricultural barriers in Old River, Middle River and Grant Line Canal have the potential to alter hydrology. The proposal of expanding the Los Vaqueros Reservoir (Phase 2) including improvements to water quality and supply reliability which may impact water diversions. Despite ongoing and potential future projects that could benefit native fishes and their habitat in Delta, it is apparent that the effects of past and present actions have resulted in a cumulative adverse effect on Delta smelt, longfin smelt, winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, late fall-run Chinook salmon, steelhead and green sturgeon.

O.10.4.1 Osmerids

This section addresses cumulative impacts on Delta smelt and longfin smelt.

No Action Alternative

The proposed components under the No Action Alternative may cause potential effects (adverse or beneficial) on Delta smelt (e.g., operations of Barker Slough Pumping Plant, Delta smelt supplementation, OMR management).

The No Action Alternative would contribute to cumulative effects on Delta smelt and longfin smelt from seasonal operations and Delta smelt habitat operations (e.g., food availability, habitat extent) and OMR management (i.e., south Delta entrainment risk). Also, there may be offsetting, potential positive effects on Delta smelt under the No Action Alternative from food subsidies (studies related to Sacramento Deepwater Ship Channel, North Delta/Colusa Basin Drain, and Suisun Marsh RRDS) and reintroduction of Delta smelt by the Fish Conservation and Culture Laboratory and the Delta Fish Species Conservation Hatchery. Except for Delta smelt supplementation, these offsetting effects under the No Action Alternative also would benefit longfin smelt. The No Action Alternative would still be expected to contribute to cumulative effects, both positive and negative, on Delta smelt and longfin smelt.

Alternatives 1–4

The action alternatives would contribute to cumulative effects on Delta smelt from seasonal operations and Delta smelt habitat operations (e.g., food availability, habitat extent) and OMR management (i.e., south Delta entrainment risk). Also, there may be offsetting, potential positive effects on Delta smelt under the action alternatives from food subsidies (studies related to Sacramento Deepwater Ship Channel, North Delta/Colusa Basin Drain, and Suisun Marsh RRDS) and reintroduction of Delta smelt by the Fish Conservation and Culture Laboratory and the Delta Fish Species Conservation Hatchery. Nevertheless, the action alternatives would still be expected to contribute to cumulative effects on Delta smelt. Expansion of the Los Vaqueros Reservoir may adjust the timing of its Delta water diversions to accommodate the life cycles of Delta aquatic species including osmerids; thus, this project would reduce species impact and providing a net benefit to the Delta environment and not contribute to cumulative effects for these species under any alternative.

Alternatives 1, 2, and 4 may result in adverse impacts on longfin smelt due to entrainment. There may be offsetting potential positive effects on Delta smelt under the action alternatives from food subsidies (studies related to Sacramento Deepwater Ship Channel, North Delta/Colusa Basin Drain, and Suisun Marsh RRDS). Nevertheless, Alternatives 1, 2, and 4 would still be expected to contribute to cumulative effects on Delta smelt. Alternative 3 may result in a benefit lessening entrainment of longfin smelt; therefore, lessening cumulative effects on Delta smelt.

O.10.4.2 Anadromous Salmonids

No Action Alternative

The No Action Alternative would contribute to cumulative effects on anadromous salmonids from seasonal operations, OMR management (south Delta entrainment risk), and Delta Cross Channel operations. However, there may be offsetting, potential positive effects under the No Action for winter-run Chinook salmon from improvements at the Tracy and Skinner fish facilities, real-time OMR restrictions and performance objectives, real-time decision-making and salvage thresholds.

Alternatives 1–4

Alternatives 1, 2 and 4 may result in adverse impacts on both entrainment risk and survival of winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon and late fall-run Chinook salmon. Thus, Alternatives 1, 2, and 4 may contribute to cumulative effects on these species. Alternatives 2 and 4 are not anticipated to contribute to cumulative effects on steelhead. However, Alternative 1 is expected to result in adverse flow effects on entrainment risk of steelhead; thus contributing to cumulative effects for this species. Construction and operations of the agricultural barriers does not coincide with the majority of juvenile salmonids migrating through the Delta; thus, these barriers would not contribute to cumulative effects for these species under any alternative.

Alternative 3 may result in a beneficial impact on both entrainment risk and survival of winter-run Chinook, particularly in wet, above normal, and below normal water year types. requirements. However, Alternative 3 would result in adverse impacts on spring-run Chinook salmon, fall-run Chinook salmon and late fall-run Chinook salmon due to entrainment.

Alternative 3 is expected to result in beneficial flow effects on entrainment risk of steelhead, relative to the No Action Alternative. Thus, Alternative 3 would contribute to cumulative impacts on spring-run Chinook salmon, fall-run Chinook salmon and late fall-run Chinook but lessen cumulative impacts on steelhead and winter-run Chinook salmon.

O.10.4.3 Green and White Sturgeon

No Action Alternative

The No Action Alternative may result in cumulative effects to green and white sturgeon from seasonal operations, OMR management (south Delta entrainment risk), and Delta Cross Channel operations. There may be offsetting, potential positive effects for green and white sturgeon from improvements at the Tracy and Skinner fish facilities, real-time OMR restrictions and performance objectives, real-time decision-making and salvage thresholds. Nevertheless, the No Action Alternative may still contribute to cumulative effects on green and white sturgeon in the Delta.

Alternatives 1–4

The action alternatives (Alternatives 1-4) are expected to result in negative effects on green and white sturgeon from seasonal operations, OMR management (south Delta entrainment risk), and Delta Cross Channel operations. There may be offsetting, potential positive effects for green and white sturgeon from improvements at the Tracy and Skinner fish facilities, real-time OMR restrictions and performance objectives, real-time decision-making and salvage thresholds. Nevertheless, the No Action Alternative may still contribute to cumulative effects on green and white sturgeon in the Delta.

O.10.4.4 Other Focal Fish Species

This section addresses cumulative effects on the Delta populations of the focal fish species not included as anadromous salmonids or green sturgeon and white sturgeon: Sacramento hitch, Sacramento splittail, hardhead, Pacific lamprey, western river lamprey, striped bass, American shad, threadfin shad, largemouth bass, smallmouth bass, spotted bass, and starry flounder. None of these is a federally listed species.

The proposed components under both the No Action Alternative and Alternatives 1-4 primarily target anadromous salmonids but some may result in population level effects to other focal species listed above. For example, reductions in Delta outflow and increased exports under Alternative 1 could have substantial adverse effects on Sacramento splittail and other native minnows due to increased entrainment and unfavorable habitat conditions in the Delta. Alternatives 1, 2, and 4 would increase exports during critical times for some native focal species, likely leading to increased entrainment. Alternative 3, on the other hand, may benefit several of the other focal species. Additionally, components like the agricultural barriers and CCF weed management under the No Action Alternative would likely have adverse effects on other focal species. Therefore, the No Action Alternative and Alternatives 1-4 may result in cumulative impacts on these species.

O.10.5 San Joaquin River

The San Joaquin River is a highly altered watershed that is currently discontinuous. Historical actions and management led to the extirpation of native fishes, including spring-run Chinook salmon that once persisted. While these impacts were acknowledged as a trade-off for other water management priorities in the past, current policy has worked to reverse the degraded river. As such, there are numerous ongoing actions in and around the San Joaquin River that may result in cumulative effects. Many of these actions are working to restore or improve conditions, so the resultant effect may not necessarily be an adverse cumulative impact.

The San Joaquin River Restoration Program (SJRRP) is a large and comprehensive effort to reverse some of the negative alterations to the upper San Joaquin River aquatic habitat while reintroducing spring-run Chinook salmon. The project manages for both fall-run and spring-run Chinook salmon alike, but has reintroduced spring-run Chinook salmon through an experimental population. The salmon population will be supported by a conservation hatchery, which operates under more significant scrutiny considering genetic diversity and overall viability. The program seeks to connect flow from Friant Dam down to the mouth of the Merced River to provide habitat capable of supporting populations of Chinook salmon in good condition. While water management and habitat restoration are significant components to the project, the overall impact on irrigators is required to be *de minimus*. In addition, hatchery production occurs in the San Joaquin watershed along the Mokelumne and Merced Rivers, at the Mokelumne Fish Hatchery and Merced River Fish Facility. Production includes fall-run Chinook salmon, which further supports the population.

Several regulatory processes are currently underway that might lead to general revisions to flow in the San Joaquin River. The Bay-Delta Water Quality Control Plan Update is seeking potential instream flow changes in increments of 10 from 35% of unimpaired flow up to 75% unimpaired flow from the lower San Joaquin, Merced, Tuolumne, and Stanislaus Rivers. This level of unimpaired flow would significantly increase outflow through the lower San Joaquin River to the Delta. FERC relicensing activity in the Merced and Tuolumne Rivers will eventually result in a new license that may increase required base flows from these tributaries to the San Joaquin River.

The No Action Alternative and the action alternatives (Alternative 1-4) do not include actions that target the San Joaquin River. Reclamation will continue to operate the San Joaquin River in accordance with the SJRRP, which is an independent action. Thus, the No Action Alternative and the action alternatives are not expected to contribute to cumulative impacts on San Joaquin River aquatic resources.

O.10.6 Stanislaus River

Natural hydrologic processes have been altered on the Stanislaus River, as they have been on most California rivers. More than 40 dams exist on the Stanislaus River. The lower Stanislaus River has been extensively developed to provide water, flood control, hydroelectric power, gravel, and conversion of floodplain habitat for agricultural and residential uses (Merz n.d.). The construction of New Melones Reservoir and its operation have resulted in a highly altered channel that has experienced gravel extraction, levee construction and removal of woody debris.

Processes and measures have occurred within the watershed to restore or improve conditions within the river, so the resultant effect may not necessarily be an adverse cumulative effect.

Processes and measures are underway in the Stanislaus River watershed. The SWRCB is updating the 2006 Bay-Delta Water Quality Control Plan (WQCP) in two phases (SWRCB 2018). The first Plan amendment (Phase 1) is focused on San Joaquin River flows and southern Sacramento-San Joaquin Delta (Delta) salinity and would modify water quality objectives (i.e., establishes minimum flows) on the Stanislaus River to protect the beneficial use of fish and wildlife and modifies the water quality objectives in the southern Delta to protect the beneficial use of agriculture. The proposed final amendments to the Bay-Delta Plan and the Final Supplemental Environmental Document for Phase I was released in July 2018 and the SED was approved in December 2018. Additionally, FERC relicensing activity of hydropower in the Stanislaus River will eventually result in a new license that may increase flows into the Stanislaus River.

The following are the proposed components that were identified in the evaluation of the alternatives to have potential effects (adverse or beneficial) on one or more of the anadromous salmonid species or runs, green and white sturgeon, and other focal fish species:

O.10.6.1 Anadromous Salmonids

This section addresses cumulative impacts on the Stanislaus River populations of steelhead and fall-run Chinook salmon.

No Action Alternative

The following components of the No Action Alternative have been identified as potentially resulting in impacts (adverse or beneficial) on anadromous salmonids in the Stanislaus River. These components include seasonal operations, ramping rates, minimum instream flows, winter instability flows and spring and fall pulse flows.

The No Action Alternative is expected to result in adverse and beneficial flow and temperature changes for both steelhead and fall-run Chinook salmon. However, these effects are not expected to reach population level impacts. Thus, the No Action Alternative is not expected to contribute to cumulative effects of anadromous salmonids in the Stanislaus River.

Alternatives 1–4

The following components of the action alternatives have been identified as potentially resulting in impacts (adverse or beneficial) on anadromous salmonids in the Stanislaus River. These components include seasonal operations (Alternatives 1-4), ramping rates (Alternatives 1-4), minimum instream flows (Alternatives 1-4), winter instability flows (Alternatives 2 and 3), spring pulse flows (Alternative 3 and 4) and fall pulse flows (Alternatives 2, 3 and 4).

All action alternatives are expected to result in beneficial and adverse flow and temperature related impacts on anadromous salmonids in the Stanislaus River. However, these effects are not expected to reach population level impacts. Thus, the action alternatives are not expected to contribute to cumulative effects of anadromous salmonids in the Stanislaus River.

O.10.6.2 Other Focal Fish Species

This section addresses cumulative effects on the Stanislaus River populations of focal fish species outside of anadromous salmonids: hardhead, Pacific lamprey, western river lamprey, striped bass, American shad, threadfin shad, largemouth bass, smallmouth bass, and spotted bass.

The proposed components under both the No Action Alternative and Alternatives 1-4 primarily target anadromous salmonids and none of them are expected to result in population level effects to other focal species listed above. Therefore, the No Action Alternative and Alternatives 1-4 are not expected to result in cumulative impacts on these species.

O.10.7 Trinity River

Major factors contributing to the cumulative adverse impacts (cumulative effects) on aquatic biological resources in the Trinity River in the project area have included dam construction, hydropower development and operations, mining and dredging in the river corridor, hatchery management, water diversions, recreational use, sport fisheries, introduction of nonnative fish species, illegal marijuana cultivation, and other management actions, water uses, and land uses. Many of these actions have resulted in altered flows on the Trinity River, reduced sediment input to downstream locations, hindered important fluvial processes which support riparian habitat and river channel dynamics, increased riparian vegetation encroachment through the reduction of vegetation scouring high flow events, reduced channel movement and the creation of unnatural levees isolating the channel from the floodplain, and other adverse effects on aquatic habitat. These alterations have led to a reduction in channel complexity and aquatic habitat for several fish species in the mainstem Trinity River downstream of Lewiston Dam. Other activities have contributed to cumulative effects by degrading habitat in the mainstem Trinity River and tributaries, increasing competition and predation on listed and sensitive fishes, and altering population genetics of listed salmonids.

Several management components have been established to mitigate for the adverse effects of dam construction on the Trinity River and are included in the TRRP and the Trinity River ROD. The TRRP includes instream flow management, mechanical channel rehabilitation, fine and coarse sediment management, watershed restoration, infrastructure improvement, and adaptive environmental assessment and monitoring. Components including sediment management and channel rehabilitation are focused on the 40-mile section of the Trinity River from Lewiston Dam to the confluence with the North Fork Trinity River (TRRP 2014). The effects of other components, including instream flow management, are intended to extend throughout the mainstem Trinity River downstream of Lewiston Dam. Since 2008, over 75 projects have been completed under the TRRP. The ROD documents actions intended to restore and maintain anadromous fishery resources in the Trinity River based on the best available scientific information, while continuing to provide water supplies for beneficial uses and power generation. The ROD specifies variable annual instream flows for the Trinity River, physical channel rehabilitation, sediment management, watershed restoration efforts, and infrastructure improvements and modifications (USDOI 2000). The Trinity River Hatchery (TRH) produces coho salmon, Chinook salmon, and steelhead to supplement regional populations of these species as mitigation for habitat and fish production lost from construction and operation of Lewiston Dam. The TRH has been in operation since 1960 but is not a component of the ROD or the TRRP.

The Klamath Dam removal and Klamath River Project are two other present actions that will contribute benefits to fish and aquatic resources in the Trinity River and Lower Klamath River by improving aquatic habitat and fish passage in the watershed. These actions involve the removal of four dams and water management in the Klamath River mainstem.

Despite ongoing and potential future projects that could benefit native Trinity River fishes and their habitat, it is apparent that the effects of past and present actions have resulted in a cumulative adverse effect on coho salmon, Chinook salmon, steelhead, green sturgeon, white sturgeon, Pacific lamprey, and American shad.

O.10.7.1 Anadromous Salmonids

No Action Alternative

The No Action Alternative will continue to implement the 2000 Trinity ROD. Although, the No Action Alternative may result in negative and beneficial changes to parameters (e.g., flows, water temperatures) important for anadromous species in the Trinity River, population level adverse impacts are not identified under the No Action Alternative. Thus, the No Action Alternative is not expected to contribute to cumulative impacts on anadromous salmonids in the Trinity River.

Alternatives 1–4

The action alternatives will continue to implement the 2000 Trinity ROD. Although, the action alternatives may result in negative and beneficial changes to parameters (e.g., flows, water temperatures) important for anadromous species in the Trinity River, population level adverse impacts are not identified under these alternatives. Thus, the action alternatives are not expected to contribute to cumulative impacts on anadromous salmonids in the Trinity River.

O.10.7.2 Green and White Sturgeon

No Action Alternative

The No Action Alternative will continue to implement the 2000 Trinity ROD. Although, the No Action Alternative may result in negative and beneficial changes to parameters (e.g., flows, water temperatures) important for green and white sturgeon in the Trinity River, population level adverse impacts are not identified under the No Action Alternative. Thus, the No Action Alternative is not expected to contribute to cumulative impacts on green and white sturgeon in the Trinity River.

Alternatives 1–4

The action alternatives will continue to implement the 2000 Trinity ROD. Although, the action alternatives may result in negative and beneficial changes to parameters (e.g., flows, water temperatures) important for green and white sturgeon in the Trinity River, population level adverse impacts are not identified under these alternatives. Thus, the action alternatives are not expected to contribute to cumulative impacts on green and white sturgeon in the Trinity River.

O.10.7.3 Other Focal Species

These species include Pacific Lamprey and American shad.

No Action Alternative

The No Action Alternative will continue to implement the 2000 Trinity ROD. The No Action Alternative is not expected to negatively impact Pacific lamprey and American shad. Thus, the No Action Alternative is not expected contribute to cumulative impacts on these species.

Alternatives 1–4

The action alternatives will continue to implement the 2000 Trinity ROD. The action alternatives are not expected to negatively impact Pacific lamprey and American shad. Thus, the action alternatives not expected contribute to cumulative impacts on these species.

O.10.8 Nearshore Pacific Ocean of the California Coast

O.10.8.1 Southern Resident Killer Whale

In general, the analysis of the No Action Alternative and Alternatives 1–4 noted that potential effects on Chinook Salmon prey for Southern Resident Killer Whale (Southern Residents) may be limited because of negligible differences between adult Chinook salmon abundance and biomass for adult Chinook salmon that occur in the Pacific Ocean that originate from the Central Valley or Trinity River. This coupled with the relatively high representation in the stocks by hatchery-origin fish, many of which are released downstream of the Delta, mean there would be limited impacts of the No Action Alternative and the action alternatives (Alternatives 1-4). Thus, the No Action Alternative and Alternatives 1-4 are not expected to contribute to cumulative impacts on Southern Resident Killer Whales.

O.10.9 Sites Reservoir and Delta Conveyance Project

The operation of Sites Reservoir may result in cumulative impacts on aquatic resources through the timing and magnitude of flow releases and seasonal water temperatures when combined with the ongoing water operations of the CVP and SWP and associated flow alterations. Potential cumulative impacts would be anticipated to be limited both spatially and temporally and minimized by operational criteria for migrating juvenile salmonids or managing to reduce potential water quality-related effects on delta smelt.

The operation of water conveyance facilities related to the Delta Conveyance Project may result in cumulative impacts on aquatic resources for winter-run Chinook salmon), Central Valley steelhead, delta smelt, and longfin smelt. Operational effects of the CVP and SWP could combine with the effects of operations of the Delta Conveyance Project. Potential cumulative impacts could result from diversions from the Sacramento River under operation of the CVP could affect fish and aquatic species in an analogous manner to that which could occur under the DCP, e.g., by reducing river flow, thereby potentially affecting migration survival for juvenile salmonids or abundance of longfin smelt through Delta outflow-abundance relationships (Sites, 2023).

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O.10.3 Federal Register Notices

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O.10.4 Water Rights

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